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ESN INFORMATION BULLETIN

This publication is an official publication of the Office of Naval Research European Office. It describes research that is being conducted in Europe and the Middle East.

Commanding Officer .... CAPT John M. Evans, USN
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92-06

In This Issue. . .

SPECIAL FOCUS—MANUFACTURING

CHEMISTRY

COMPUTER SCIENCE

MATERIALS

EC-Sponsored Research in Design and Manufacturing

by Daniel E. Whitney, who was the Liaison Scientist for Manufacturing at the Office of Naval Research European Office. Dr. Whitney is at the Charles Stark Draper Laboratory, Inc., Cambridge, Massachusetts.

Keywords: Intelligent Manufacturing Systems; BRITE-EURAM; European Community; robotics; mechatronics

Headline: "International cooperation is basic to international competitiveness. In fact, international is like interdisciplinary, the only way to get ahead," Prof. Frank-Lothar Krause, Fraunhofer Institute of Production Technology (IPK), Berlin

SUMMARY

The European Community (EC) funds several billion dollars worth of technologically targeted research each year. A significant amount of this goes for design, manufacturing, and the associated information technology and infrastructure to support design and manufacturing. The desired result was to boost Europe's economic and technological power. However, this result either has not been attained, has been derailed by larger economic forces, or (most likely) will take longer than the planners had hoped. A large amount of innovative research has been sponsored and, more importantly, vital international partnerships have been established that will bear fruit as Europe becomes more united.

Major changes, reassessments, and new programs are emerging within the EC's research programs. The two research Directorates reported on here will be merged to eliminate overlaps in objectives and projects. In addition, the Intelligent Manufacturing Systems (IMS) program proposed by the Japanese is causing important international connections to be established and new methods of cooperating to be developed. Underlying the policy issues are basic research questions such as whether manufacturing research is important enough to be funded, and whether a top-down application of information technology (IT) research and development (R&D) alone can solve problems in design and manufacturing.

The EC programs clearly represent a large and broadly diverse attempt to highlight technically and economically important research areas and get results that can be used. As with both U.S. and Japanese efforts of a similar nature, they are financially small compared to the total resources of industry. The long-range hope is that the cumulative effect will be large. Nearer-term, the EC programs have problems similar to those in other regions: small size per project or small share per participant, the possibility that the most important research is kept within the companies, a tendency toward multiple technical-political objectives that dilute resources, and duplication among programs.

This report describes some of the practical results and difficulties of individual projects. Others will follow in articles that cover visits in Leuven and Berlin. An article on visits to U.K. design research centers[1] comments on attempts by the Department of Trade and Industry (DTI) to actively manage some of its research projects.

BACKGROUND

This article is based on interviews with the main EC design-manufacturing program managers, plus some comments by a member of the U.S. Mission to the EC:

- David Miles, EC Research Directorate General XII, in charge of planning the BRITE-EURAM program, which funds research into materials, manufacturing processes and design, and computerized methods of operating complex factories;

- Patricia Mac Conaill, Head of Division, EC Research Directorate General XIII, in charge of administering the ESPRIT manufacturing research programs (overall, ESPRIT funds research and applications in the areas of microelectronics, software engineering and information processing systems, advanced business and home systems, computer integrated manufacturing and engineering, high performance computing, and basic research);[2] and

- Anthony Rock, Economic Affairs Office of the U.S. Mission to the EC, monitoring and participating in the Intelligent Manufacturing Systems (IMS) program negotiations

Questions pursued included

- what research is being sponsored, what is being accomplished, and what are the future plans;

- is technology transfer being achieved;

- what is the trend of research funding;

- in design and manufacturing, what is the balance between top-down research (seeking generic solutions to most or all design/manufacturing problems) and bottom-up research (focused on a particular technology or type of product); and

- what is the importance of design in these research programs and how is design research framed.

The following remarks reflect frank discussions with several EC program managers, during which strengths and weaknesses of national and international programs world-wide were discussed. These program managers were kind enough to share their experiences with me. The spirit of these discussions was constructive, and the purpose was not to reveal faults. What follows is my best understanding of their views. My own comments and views are called out specifically.

EC RESEARCH PROGRAM STRUCTURE

ESPRIT and BRITE-EURAM are major components of the EC Framework Program for R&D. For the time period 1991-94, the total Framework funding is 5.7 billion ECU. Of this, ESPRIT has about 2.2 billion and BRITE-EURAM has 748 million. (One ECU = $1.30, approximately, as of July 1, 1992.) Table 1 shows a breakdown of funding by topic area. ESPRIT and BRITE/EURAM programs have been combined in this table.[3]

I got some insight into EC research programs during the IEEE Robotics and Automation Conference[4] I attended earlier this spring, where I attended a session describing large national research programs and obtained literature on ESPRIT at the exhibition. Japanese, U.K., EC, and U.S. (mainly NASA) robotics programs were described briefly in a panel session chaired by Dr. Norman Caplan of the National Science Foundation (NSF). One immediately gets an impression of scatter from the EC programs. The Commission funds up to 600 projects at a time in all its technical areas. Projects are performed by teams that have from 5 (average) to as many as 20 members, and industrial partners from at least two member states (intentionally). Industry cost- shares these programs at the rate of about 50%. Small businesses participate in 67% of the projects, and universities in 81%.

According to Mrs. Mac Conaill, the projects are managed by a staff member of the designated coordinating contractor. The Commission staff (assisted by independent external reviewers) are responsible for monitoring the technical and financial performance of projects; they can apply pressure for corrective action if this is deemed appropriate. Typical projects apparently run in parallel, with "results being shared at the end of the project," according to several comments I heard. The projects are usefully long, typically three to five years. However, the funding levels seem small to me—often five to ten man-years per year spread

Table 1 — 1990-1994 EC Framework Budget

Program Element	1990-1994 Budget (Millions of ECU)	Program Total
I. ENABLING TECHNOLOGIES		
1. Information and Communications Technologies		2,221
Information Technologies	1352	
Communication Technologies	489	
Telematic Systems	380	
2. Industrial and Materials Technologies		888
Industrial and Materials Technologies	748	
Measurement and Testing	140	
II. MANAGEMENT OF NATURAL RESOURSES		
3. Environment		518
Environment	414	
Marine Science and Technology	104	
4. Life Sciences and Technology		741
Biotechnology	164	
Agricultural and Agro-Industrial Research	333	
Biomedical and Health Research	133	
Life Sciences and Technologies for Developing Countries		
5. Energy		814
Non-Nuclear Energy	157	
Nuclear Fission Energy	199	
Controlled Nuclear Fusion	458	
III. MANAGEMENT OF INTELLECTUAL RESOURCES		
6. Human Capital and Mobility		518
	TOTAL	5700

over five to ten participants, making it difficult to achieve a critical mass.

Despite the statements in the ESPRIT brochure of achievements,[2] there appears to be less technology transfer and application of results than people had hoped. This report does not attempt to analyze this, but a few examples will describe some of the problems. These problems are not unique to EC programs, except for the deliberate policy of having participants from many countries, and they occur in Japanese and U.S. programs as well. The instructive opportunity is to see how EC planners attack these problems so that we ourselves might learn.

Example 1: (ESPRIT 1561) This was a robot path control project in which the Katholieke Universiteit (KU) Leuven (Belgium) took part. It was organized by Bertin & Cie., a French engineering firm, and included the German firms AEG (a maker of robot controllers), and KUKA (a robot manufacturer). KU Leuven's part was to design sensors to install in the robot's joints plus computer algorithms to insert in the robot controller so that trajectory tracking accuracy could be improved. The university applied this to one of their KUKA robots and achieved error reduction from 2 mm before to 0.5 mm after. For many kinds of trajectory-intensive tasks, this is a useful reduction. The results have not been applied, however. As the story is related by KU Leuven researchers, AEG does not make controllers for KUKA robots; Siemens makes them. Furthermore, KUKA was not interested in applying the results since they did not see the need for this reduction (despite being surprised that their robot was so inaccurate) because they would not incur the cost of adding even a single sensor. Had Siemens been a part of the original team, the outcome might have been different.

Example 2: This is a feature-based design project at the Fraunhofer Institute in Berlin whose aim is to create new CAD (computer-aided design) systems that provide both form features (holes, slots, etc.) and semantic features (information about the form features such as "four of them, spaced equally around a circle of radius *x*"). This is an innovative and useful project, with many long-term implications for use of computers in design. (It is part of the large IMPPACT project, ESPRIT Project 2165.) However, there will apparently be no near-term use of the results, in part because the CAD firm on the research team went bankrupt half way through the program. No follow-on funding could be obtained from ESPRIT. A proposal has been submitted to BRITE (see below for the reason), but BRITE is a much smaller program and no one knows if the project will be funded.

These two examples cannot necessarily be assumed typical, but their problems are similar: they appear to have been planned opportunistically and did not receive some important midcourse corrections that could have improved the chances for technology transfer. The EC staffs are too small, and there are too many projects to permit effective oversight of every one.

Another factor is the obvious overlap between BRITE-EURAM and ESPRIT in the areas of design, manufacturing, and computer-integrated manufacturing and engineering (CIME). In their respective calls for proposals, the research project descriptions in certain areas of these programs are almost identical; this causes confusion and occasional conflict. The directors of the respective programs and several researchers I spoke to all acknowledge this overlap. At present, proposers do not know where to submit their proposals, and thus they submit to both. Research administrators spend time mending fences and culling duplicate proposals.

Discussion with EC research administrators indicates that this overlap "grew like Topsy" when BRITE program managers found that their original focus on machine tools was not sufficient to encompass the real problems, which extend inevitably to information technology. (As of late July, EC administrators have removed the overlap by combining some of the activities of [Directorate Generale] DG XII and DG XIII.) One can conclude that the EC is still searching for the right formula for using research as a way to improve Europe's technology and manufacturing. The current formula grew while the intellectual issues were still forming, and it clearly is headed for revision. Because an underlying aim of EC research is to bring workers in different countries together, we should be cautious about drawing conclusions for our own domestic programs. Given this caveat, it appears that EC programs get too little review and direction, and that their intended technology transfer

objectives are not backed up by specific technology transfer plans. The same is true of most U.S. research programs.

In addition, an early confidence that information technology could solve problems by itself seems to have receded, but it has not been replaced by an alternate strategy. Any such strategy must come to grips with the fact that many design and manufacturing processes are not well understood. In addition, such understanding may not have the broad generic character that researchers expect based on past experience with more purely scientific endeavors. Therefore, a frankly bottom-up approach that acknowledges the uniqueness of each problem needs to be blended with the top-down generic information technology approach. This challenge applies to domestic U.S. programs as well.

VISITS TO EC RESEARCH PROGRAM DIRECTORS

David Miles, BRITE-EURAM (research into materials, manufacturing processes and design, and computerized methods of operating complex factories)

His program is a mixture of materials research and design/manufacturing, with about equal funding allocations for each. His budget for 1991-1994 is ECU 748 million, allocated as follows:

- raw materials and recycling: 12%
- materials in general: 35%
- design and manufacturing: 45%
- aeronautics: 8%.

The latest round of funding drew proposals in April 1992 and another round ends in February 1993. Miles' former job was in the U.K.'s Department of Trade and Industry; he was in charge of Technology Awareness, trying to get companies to investigate and adopt new manufacturing methods. He feels that management was the reason companies did not adopt these new methods, a fact he is trying with difficulty to factor into the BRITE program.

He related a story of a company that introduced flexible manufacturing, only to find that the equipment could not be run overnight because the tools broke. In the old manual system, the machinists avoided tool breakage by adjusting the cut depth according to the variations in the size of incoming castings. To help the FMS (flexible manufacturing system) overcome tool breakage, the company paid extra for more accurately made castings. These castings contained less excess material and thus took only half as long to machine. The result was that tool breakage stopped, but now half the machines in the FMS are unused. The lesson is that companies must evaluate whether they are ready for, or even need computer-integrated manufacturing (CIM). This is one of many "system issues" that neither companies nor the research programs recognize. (People like myself and others with consulting experience can tell dozens of similar stories.)

The issue is acute because BRITE was designed to be "bottom-up;" this means that it is supposed to be driven by the needs of users. But users' needs are not well understood by researchers, or by the users themselves. He contrasted this bottom-up emphasis with ESPRIT, which has until recently been driven by the needs of vendors of new technology, a cause for some criticism of ESPRIT. The new CIME (Computer-Integrated Manufacturing and Engineering) program in ESPRIT (see below) was designed to include vendors and users.

The original list of research topics for BRITE/EURAM was developed by methods similar to those used in the U.S.: workshops of experts from industry and academia were held and consensus lists of topics were drawn up. In accord with EC methods, these lists were passed around the member states and reviewed. The result was that they grew unsystematically, and no set of priorities was developed. Miles, therefore, cannot rank the incoming proposals.

Two remedies have occurred to him. One is a Critical Technologies list, similar to those developed in the U.S. He thinks that Europe's list would be comparable and would contain obvious elements. Any list made for the military more than two years ago, for example, would have to be drastically revised. The other remedy is to look at the whole supplier chain, identify necessary steps in producing products, find technology gaps, and focus research on them. He has adopted this approach but is not finished.

He notes that this approach has a shortcoming with regard to design, whose necessary elements and procedures are not well understood. In particular, the constraints on products are changing rapidly; recycling and environmental effects are increasing in importance. No one knows how to systematically take these into account during design, which is the only place such accounting can occur. On this point he cautions that too much responsibility can be placed on design, and it can become overburdened. This makes design so complex that no one can accomplish it, especially small businesses.

Individual project summaries[5] show a multitude of interesting topics (and one hopes that they will bear fruit). Some examples include:

- A Structural Methodology for the Ship Predesign Process (Project BE-4227)
- Design Methodology for Durability of Mechanical Components Based on Reliability Approaches (BE-3051)
- Design Methodologies for Engineering Component Properties (BE-3413)
- Power Train Noise/Vibration Prediction (BE-4126)
- Intelligent Composites Containing Fiber Optic Measuring Networks for Continuous Self-Diagnosis (BE-2361)
- Simultaneous Engineering System for Applications in Mechanical Engineering (actually a feature-based design system, not a communications infrastructure project) (BE-4539)
- Integrated Calculation in a Design System (BE-4471)
- Development of Standardized Material Transport Devices for the Sequential Automation of the Processing of Flexible Materials (applied to the garment industry, not aircraft or car parts) (BE-1535)

Note: projects with numbers below 2000 began before 1988 and are probably finished. Projects with numbers over 4000 are probably new this year or last.

Patricia Mac Conaill, ESPRIT's CIME and IMS Programs (Computer Integrated Manufacturing and Engineering; Intelligent Manufacturing Systems)

The ESPRIT program has had two Phases and is now in Phase III. The funding history is:

- Phase I (1984-88): ECU 1.5 billion (12% was for CIM)
- Phase II (1988-92): ECU 3.2 billion (16.5% for CIM)
- Phase III (1991-94, launched during the final year of Phase II): ECU 2.2 billion (20% targeted for CIME).

The "E" in CIME is new with the start of ESPRIT Phase III in 1991; it reflects a strategic decision to apply CIM methods and technologies in areas outside of traditional manufacturing, such as agriculture and construction. This decision appears to include extending the principles of CIM beyond data exchange, networks, and traditional metal cutting to include the whole product life cycle. These new areas are the source of more proposals than the EC expected, so budgets in the traditional areas are being squeezed. Mrs. Mac Conaill has had an uphill battle keeping CIM funded, since manufacturing has not been seen as important by higher management in the EC research establishment.

A major role for her has been to foster and develop a community of researchers in the member states, both in industry and academia, who agree on a broad research agenda. The differences in culture and style between the member states must always be kept in mind. For these reasons, she is particularly pleased with progress in data exchange standards and a technology diffusion program called CIMEUROPE. The latter helps small and medium size enterprises (SMEs) find partners for technology transfer, consulting,

business contacts, and EC research program participation. Its activities include an annual conference where project teams give talks and SMEs can learn what is going on.

I mentioned to her the 150 or so Japanese technology "extensions stations" run by the national and prefectural governments that do the same thing. The EC cannot sponsor such activities, she says.

My impression from talking to her, as well as to others, is that the EC programs, regardless of degree of technical success, have achieved something Europe has never had before, namely, this community of people in industry, universities, and government who understand some of the technical challenges and now know each other as well. Mrs. Mac Conaill is one of the builders of this community. She has also kept up an informal collaboration with the National Science Foundation, the National Institute of Standards and Technology, and until recently, with CALS (the computer-aided logistics system).

I believe that she, too, shares some of the misgivings that David Miles expressed about the way the programs have grown. As he said, they are very much the result of an increasing realization of the central character of information technology (IT) in many areas of manufacturing. The BRITE program has responded by expanding from the bottom, adding IT issues to shop floor problems. ESPRIT has responded from the top, attempting to provide generic capabilities like data interchange, product models, and database technology.

Important differences can be seen in the emphases that various EC states put on IT. She observes that in the U.K. and in the U.S., IT applications tend to be driven by data processing departments, which are strong in computer science knowledge, less strong in applications experience. In Germany, Japan, and Switzerland, where engineers are held in higher esteem, the user departments are much more influential and may often be the drivers. In my opinion, it is also easier to convince researchers there that a bottom-up approach is needed when portions of the basic engineering are not yet well understood; IT applications must be built on a sound engineering knowledge base and cannot be expected to replace it. In ESPRIT CIM, Mrs. Mac Conaill has tried to build bridges between the computer scientists and the manufacturing engineers.

Willy Van Puymbroek, CIME, and Coordinator for IMS European Operations

Mr. Van Puymbroek, assistant to Mrs. Mac Conaill, explained the CIME program to me, providing a detailed breakdown of the topics covered. Funding averages ECU 130 million per year; it covers 60 projects now, with 60 more coming onstream next year. The average is thus a bit more than one million ECUs per project per year.

The overall goals of CIME are to improve European industry's competitive position by:

- applying IT solutions in processes and products, with emphasis on "applying;"
- seizing new markets; and
- producing cleaner industrial processes.

The application areas are discrete parts manufacturing and its associated processes; engineering, mining and extracting of materials; construction; and agriculture. This work is divided into IT architecture and infrastructure, management and design of enterprises (all the necessary software for CIME), and mechatronics, robotics, and sensors (all the hardware necessary for CIME).

The architecture issues to be dealt with include open architectures and neutral data, "information engineering and management," how to migrate to an open environment, and how to achieve cost-effective integration of software tools. These are user-driven concerns and are similar to the priorities of many U.S. software researchers.

Under design and management of enterprises, he listed

- integration of software tools into systems;
- the human and organizational issues;
- concurrent engineering (which here means many designers working on the same design at the same time);
- manufacturing and the environment;
- consideration of the entire logistical chain from raw material to end user;

- economics and performance monitoring of CIME; and
- quality management.

Under mechatronics, he listed

- design and modeling of multidisciplinary items;
- coherent database and interface specifications for multitechnology activities; and
- micromachines.

These are very extensive lists and appear to reflect some of the cumulative effects of long-term community discussions mentioned by Mr. Miles, as well as some obvious overlaps with BRITE.

Among the accomplishments he cited are the program's influence on standards, especially the STEP (Standard for Technical Exchange of Product data) process; some neutral data definitions; new products such as open architectures, interface boards, and CAD tools; several actual CIM implementations; and enhanced education and training programs.

An outsider is bound to observe that, except for the STEP activity, many of these topics are being done as well or better by private industry in Japan and several places in the U.S. The question then is, what are these programs doing differently and are they models that we should observe more carefully? On balance my opinion is that they have the same difficulties that our national research programs have, namely, a certain lack of sharp focus and priorities, imprecise goals, small size per project, and mixed signals (international collaboration vs physical/intellectual focus, technical horsepower vs SME involvement).

Again, the project synopses[2] list many of potential interest. For example:

- *Integrated Information Processing for Design, Planning, and Control of Assembly* (Project 384). I happen to know some of the history of this project. It includes research areas I have worked in, and I kept in touch with some of the researchers while it was ongoing. It was based on the assumption that there was a need for a real-time assembly process planner for low-volume robotic assembly. The project produced some interesting robotic demonstrations. The researchers developed ad hoc and theoretically based assembly planning methods as well. However, the deeper need is for assembly planning as part of design, not as part of manufacturing.[4] The researchers ran afoul of the need to create fixtures (something David Strip faced squarely and creatively) and the project never generated any applications as far as I know.

- *Control Systems for Integrated Manufacturing* (Project 477)

- *The Application of CIM to Welded Fabrication* (Project 595). The participants were the Welding Institute, Cambridge, U.K. (one of the premier welding research laboratories in the world) and several Danish and Italian shipyards. The summary says that the results have been adopted by the yards, but this is a notoriously difficult area in which to apply IT and automation.

- *Computer-aided Engineering Software for Advanced Workstations in the CIM Environment* (Project 1062). This project was applied to CIM in the electronics industry.

- *Integrated Modeling of Products and Processes Using Advanced Computer Technologies* (Project 2165). This project is aimed at computerizing design and process planning of sheet metal and free-surface solid parts, and at making the creation of software for same more efficient.

- *Knowledge-based Planning and Control in Manufacturing Environments* (Project 2457)

- *CIM Vision System* (Project 5194). This project promises an integrated approach to vision systems that can recognize and inspect manufactured parts.

- *High-performance Computing for Multidisciplinary Dynamic Simulation of Mechanisms* (Project 5524). Design of robots, cranes, windmills, and other large machines are the targets of this simulation software

project. Its output is expected to "create a competing alternative in a market presently dominated by the U.S."

- *Application of CIM Concepts, Architectures, and Technology to Computer-Integrated Agriculture* (Project 5605). "The objectives of this exploratory project are to examine existing information technology used in agriculture, evaluate the future requirements..., design an architecture..., and describe possible applications."

Katherine Tierney, IMS European Secretariat

Ms. Tierney joined ESPRIT CIME in October 1991 to assist Mrs. Mac Conaill in setting up the IMS (Intelligent Manufacturing Systems) program. The IMS was presented by the Japanese to DG XIII in November 1989. After the original Japanese call for proposals, the U.S. Department of Commerce requested that U.S. contacts be handled under the provisions of existing U.S.-Japan commercial treaties. A long series of informal trilateral discussions have taken place to determine methods of funding, clarify ownership of intellectual property rights (IPR), and reduce the academic character in favor of one more oriented to industry.

The current status of these negotiations is as follows:

1. Instead of launching the IMS as originally proposed, there will be a feasibility study lasting about two years, during which the "modalities" (ways of working together—a prime concern of the EC, according to Mr. Rock), IPR, funding mechanisms, and overall viability of the IMS will be assessed.

2. A complex committee structure has emerged, giving rise to some concern that bureaucracy will dominate the program. This structure consists of a Steering Committee, a Technical Committee, and an IPR Committee.

3. The Technical Committee has recently agreed on six research themes for the feasibility study period:
    - enterprise integration,
    - global manufacturing,
    - system component technologies,
    - clean manufacturing (environmental concerns),
    - human and organizational aspects, and
    - advanced materials processing.

This list resulted from pruning down 21 topics submitted by the Japanese, a "green-field" position by the Europeans, and no list at all submitted by the U.S. (who proposed an "open ended" approach). A final list of topics is expected to emerge from a meeting planned for July 1992, and the first projects are supposed to start in January 1993.

It takes a lot of discussion to bring about big projects; both Japan and the EC have benefitted from existing (inter-) national infrastructures for doing these negotiations. This is a further lesson in how much work it takes to establish collaborative projects. [My article on Telemechanique[6] contains a remark by a French research manager: ESPRIT projects last three years, of which the first 1.5 are used to establish a common technical vocabulary and understanding of the partners' goals and methods. I discussed this issue with an American Professor of Management at Cranfield Institute of Technology (U.K.) whom I met on a bus. He said, "We all speak English and look alike so we assume that our cultures are the same. This mistake takes a long time to discover and correct."]

Mrs. Mac Conaill also commented that some of the international and technical issues remain indistinct and may always be because of the strong differences in approach and style among both researchers and government officials. These show up internationally in different regional emphases (EC concern with modalities, Japanese ability to merge government and industrial interests, U.S. need to coordinate both administration and congressional interests). Mr. Rock pointed out that they also show up technically in the attitude toward information technology. As both Japan and the EC increase their focus on this area and recognize its pervasive character, the U.S. with its strength in software tends to proceed carefully in its international IT cooperation.

Interestingly, some knowledgeable people also suspect that neither IMS nor ESPRIT will attract

the most interesting or advanced research, which the companies will carry on privately. However, the companies will discover each other through these mechanisms and take advantage of the EC's easier rules regarding cooperation between companies compared to the U.S. [This prediction is confirmed by the strategy planned by Dassault Systemes for their new ESPRIT project on factory assembly planning software (Project SCOPES, #6562). The project—to be described in another article—will deliver only specifications, not code. Dassault will prototype the code with its own funds and include the modules in its CATIA solid modeling software if they appear promising.]

Recent comments about the "failure" of Japan's 5th Generation Computing project draw similar conclusions. The large technical goals were not achieved, but an infrastructure was built, the most important part being a new cadre of software engineers. In the U.S., the Apollo project (NOT a failure) had this same effect 30 years ago: it generated thousands of skilled technical and system programmers who fanned out into U.S. industry in the 1970s.

CONCLUSIONS

The "right way" to manage large national research programs has yet to be found. The EC way seems to me to combine too many objectives, such as having many participants, small businesses, and international cooperation in every project. These infrastructure objectives can inhibit the technical objectives, according to some researchers with whom I have spoken. The EC needs to decide whether it has developed enough maturity in international cooperation that the infrastructure objectives can be subordinated to the technical ones.

In the U.K., the Department of Trade and Industry and the Science and Engineering Research Council[1] have begun establishing milestones and reviewing major university research projects every 12 or even 9 months. This is quite uncomfortable to the researchers, who are thereby placed in an industrial setting of schedules and deadlines. Basic research can hardly survive in such an environment, but focused research having a large technology transfer component that seeks to fill identified national needs may have to be carried out this way.

The U.S. currently has two models for nationally funded R&D: the National Science Foundation and Department of Defense programs such as those at the Defense Advanced Projects Agency (DARPA) and the Office of Naval Research (ONR). NSF's programs focus on basic research and are largely unmanaged in the sense that university researchers submit proposals in response to loosely worded calls. Peer review largely determines what gets funded, so a coordinated program is hard to form. Also, no provisions are made for funding applied research or technology transfer, and international cooperation is voluntary. DARPA projects are peer reviewed, but the program managers are obliged to form coordinated programs and regularly review the progress of the projects. Again, technology transfer, industrial participation, and international cooperation are voluntary.

I doubt that the EC model is a good one for us to follow, but it is important to note that we have not tried international research projects on any significant scale, much to our disadvantage in my opinion. The IMS will be our first opportunity, and our participation will be managed by industry. The new U.K. model of frequent reviews has not been in place long enough for conclusions to be drawn.

The U.S. has also not tried funding university research that is based on identified industrial needs or that contains an explicit technology transfer plan. However, I believe that there will be increasing pressure to "get results" from nationally and internationally funded research. (Since this article was written, the National Science Board has recommended more attention to industry needs in sponsored research.) In addition, large-scale international projects will become more common in the future. We should therefore watch existing foreign programs carefully to see how they develop. We should also begin participating in them more actively.

REFERENCES

1. Daniel E. Whitney, "The U.K. Government Program in Engineering Design Research," *ESNIB* **92-05**, 253-257 (1992).

2. *ESPRIT Progress and Results, 1991*, published by the Commission of the European

Community, DG XII, pp. 13-14 (available from UNIPUB, 4611-F Assembly Drive, Lanham, MD 20706-4391).

3. *Information and Communication Technologies in Europe*, published by the Commission of the European Community, DG XIII, 1992, p. 113 (available from UNIPUB, 4611-F Assembly Drive, Lanham, MD 20706-4391).

4. Daniel E. Whitney, "Robotics in Theory, Robotics in Practice: 1992 IEEE Robotics and Automation Conference," *ESNIB* **92-05**, 244-252 (1992).

5. *BRITE-EURAM Programme Synopses of Current Projects 1990-1991*, Brussels: ECSC-EEC-EAEC, 1991 (available from UNIPUB, 4611-F Assembly Drive, Lanham, MD 20706-4391).

6. Daniel E. Whitney, "Systematic Design of Modular Products at Telemechanique," *ESNIB*, to appear.

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Design Research and an Industrial Application of Systematic Design Methodologies

by Daniel E. Whitney

KEYWORDS: Fraunhofer Institute; Technical University of Berlin; computer-aided design; design systematics; semantic features

SUMMARY

A significant portion of design research in Germany is carried out by mechanical engineers who focus on basic issues like machine elements. In some cases they appear to have backed into computerization of design and have not made many significant collaborations with computer science researchers. Their research thus tends to emphasize the mechanical side and de-emphasize the information technology side. So it is primarily "bottom-up," stressing the basic processes (design of gears or mechanical systems).

The students I visited in Berlin have more confidence in the potential for expert systems than the professors do: the students cannot see another way to capture all the diverse criteria that designers must consider; the professors doubt that the necessary expertise can ever be captured by this technique.

This article is based on visits and interviews with design researchers Prof. Frank-Lothar Krause

at the Fraunhofer Institute of Production Technology (IPK), Prof. Wolfgang Beitz of the Technical University of Berlin (TUB), and their students.

"Design" can be divided into several phases. Two important phases are *conceptualizing* and *detailing*. Professor Beitz is trying to combine these with a technique called Systematic Design. Professor Krause is working more at the detail level, trying to strengthen the engineering aspects of geometry creation as well as the links between design and production. Feature-based design is the main technique being applied. Both want to include search and conflict resolution but have not really made provisions for doing so.

I got a close-up look at how reunification is affecting this city and these two institutes. The TUB has 34000 students, including 20% from the former DDR. The western students say that the "easties" are "different," fairly well educated but "not free" in their expression in or out of class. The one eastie I had a chance to talk to privately said that people from his side are astounded by the west's concentration on money. But he is part of and witness to a sharp contraction in funds. Berlin has lost its 20% subsidy from Bonn, and TUB has had to shrink its 22 faculties down to 10, along with a budget cut. Both Krause and Beitz are scrambling for research funds, having seen projects end without follow-ons coming through. The Bonn government is advising the researchers to seek funding from the EC but this, too, is proving difficult. Both of the laboratories I visited have recently failed to get renewals of large EC grants.

Professor Frank-Lothar Krause, Fraunhofer Institute for Production Systems and Design Technology (IPK), Berlin, Director for Design Technology and holder of the chair in Industrial Information Technology at TUB.

Professor Krause is very familiar with Japan, both the researchers and the companies. (By contrast, Prof. Beitz said he is not.) Professor Kimura visits regularly from Tokyo, and the two are planning an IMS (intelligent manufacturing system) proposal. On the wall over his desk are two photos distributed by Toyota at several recent international committee meetings and conferences: before and after in finding design errors under the hood of a car. "Before" shows designers crawling around on the floor over an enlarged drawing. "After" shows them sitting around a projection television looking at a multicolored wire frame drawing. "International cooperation is basic to international competitiveness. In fact, international is like interdisciplinary—the only way to get ahead," he said.

IPK was started by Prof. Gunther Spur in 1976. It is allied with the Institute for Machine Tool and Manufacturing Technology (IWF), which was founded by Kaiser Wilhelm II in 1904 as part of the TUB. The combination today is called The Berlin Production Technology Center. It is now in an enormous new circular building whose outer ring holds offices that look down on a huge circular central laboratory/atrium. IPK's budget is currently around 25M DM (about 1.55 DM per $1, as of August 1992), of which 13% comes from the Fraunhofer society, 50% from competitive industrial contracts, and the rest from competitive research funded by Bonn or the EC.

Professor Krause said that of some 100 Ph.D.s who have graduated over the last 40 years, 13% are in top management and 40% are in middle management; the rest are engineers or consultants (22%) and are at universities (25%). Thus IPK has succeeded in having a strong effect on how German industry is managed. In the U.S., most such people would go to universities right after graduating. This is unheard-of in Germany, where one must have at least 5, preferably 10, years of industrial experience before starting to teach and do research. He is amazed at some of the Ph.D. theses and papers he sees from the U.S. "They're all equations—no applications, no prototypes."

The Fraunhofer Institute for Production Systems and Design Technology (IPK) and the Institute for Machine Tool and Manufacturing Technology (IWF) are divided into departments, and some of the professors hold dual appointments (Prof. Spur is head of both):

IPK

Robot Systems - formerly Prof. Gerard Duelen, now retired but not yet replaced
Design Technology - Prof. Krause
System Planning - Dr. Kai Mertins
Process Technology - Dr. Wolfgang Adam
Computer Engineering for Machine Tools - Dr. August Pothast

Service Technology - Prof. Spur (education and knowledge engineering)

IWF

Machine Tools - Prof. Spur
Manufacturing Technology - Prof. Spur
Assembly Technology - Prof. Gunther Seliger
Industrial Information Technology - Prof. Krause
Control Technology - Prof. Duelen
Quality Science - Prof. Gerd Kamiske

Professor Krause deals with design, especially computer-aided design (CAD), a field he has pursued throughout his entire 25-year career. He says he and Prof. Spur did everything Doug Ross and Ivan Sutherland did in America, just 10 years later, following the same intellectual path: numerical control came first, followed by the idea that if the computer could plot the cutter paths that make the shape, the computer could hold the shape, too. His CAD department has 40 full-time staff members and many TUB students. There are four activities:

- Design systematics (NOT what Prof. Beitz does, although Beitz uses exactly the same title.)

The goal here is to enhance the use of existing CAD tools as well as to speed up creation of new ones. This has to be made more efficient and user-driven, he says. He agrees with the Japanese that only the users know what they need, so they should be empowered to make their own. There is no such thing as generic CAD, he says. He also feels that at best CAD can help the designer; it cannot automate the design. Expert systems and knowledge bases will just be sources of organized data that speed up human decision-making.

- Systems ergonomics

This group works on scanning existing drawings and interpreting the results. He is concerned about this effort; the problem is really difficult, and industry is not strongly interested. (Philippe Villers told me in 1974 that he was trying the same thing at Computervision. It finally became a special machine for the U.S. Geological Survey that scanned maps, but it never became a design tool.) Another activity of this group is similar to work being done by Herb Voelcker at Cornell University: creation of parallel computing engines to speed up three-dimensional geometry processing. It works by splitting the geometry into three levels of granularity, perhaps like the octree approach. Currently, three processors run on a VME bus. When I asked about the potential for commercializing this effort, he became pessimistic: "German companies do not have long-term strategies. Think of Nissan saying they will be a paperless company in five years! No German company has such an objective."

- Geometric Modeling

This clearly is his favorite activity. It also probably is the one where he has made the most contributions—starting with the COMPAC solid modeler in the early 1970s. Now they use ACIS, a commercial modeler with an open architecture. His goal here is very broad and ambitious, namely to build up feature-based design so that it encompasses feature modeling, product performance simulation, and physical modeling (finite elements, for example). The goal is to create a product model so that the same data can be used for all these activities. In this respect, his work closely resembles that of Kimura and Yoshikawa.

Professor Krause has been careful to define two kinds of features, the traditional form features and the non-form ones that he calls semantic features. He separated these two in order to confront the PDES/STEP community, which recognizes only the traditional kind. A nice example of a semantic feature is "X number of something arranged equally spaced in a circle of radius Y." Another is a "centering or pilot hole," which automatically will be positioned symmetrically once the designer has indicated what surface to place it in. A third is any kind of technology description or constraint, such as a surface roughness or the fact that a certain boundary must not be pierced or broken by any other feature.

The output of the design module is in the EXPRESS language, a part of the PDES/STEP activity. This guarantees that the output will be readable by any other software that conforms to the

standard. The data are stored in an object-oriented database, with forward and backward links between the feature modeler and the geometry engine. This means that design changes in either model will be automatically reflected in the other. This is a nice feature that Prof. Beitz, who uses CATIA, cannot replicate because current versions of CATIA are in a closed architecture and do not permit its modeler to be driven from another program.

This work was demonstrated for me by a research engineer. It is impressive. However, it really focuses on individual features. He could not explain any overall structure to hold it together. For example, the student has provided for constraints and parametric descriptions of features but seems to be unaware of conflict in design that leads to the need to revise. Thus the student has provided no way to see how the constraints and parameters should be altered to meet a new requirement or resolve a conflict. (The same provision is also lacking in Prof. Beitz' work. See below.) More worrisome is the fact that this important project has stopped for lack of funding because ESPRIT turned down the follow-on proposal.

- Technology planning

This means deciding how to make something, including equipment selection and process planning. He has had a hard time convincing others that this is really part of design. "It simulates manufacturing, so how better to know if design for manufacture has been achieved?" He feels that some companies are ahead intellectually since technology planning has been taken over by the product design department. (I found the Japanese of two minds on this; some favor integration in one department or even in one person while others want separate departments. Companies in faster-moving technologies like video cameras wanted the former, thinking it might save time. Companies in slower-moving technologies like cars favored the latter, noting that car manufacture takes a great deal of special knowledge.)

The topics he works on include FMS (flexible manufacturing system) design, laser cutting, fixture and clamping design, scheduling, and tool management. Interestingly, he says that expert systems and knowledge bases seem to be more necessary here than in design because every process and every product is different. There is such a tight coupling between processes, tools, machines, and products, and only people have all the knowledge, which they got from shop floor experience.

General Remarks

Professor Krause expanded on the last item above, remarking that designers are taught in school, while process people come up from the shop. He feels that, even in Germany, designers do not have enough contact with the shop. The education system creates specialists, just like in the U.S. He admires not only Japan's more general education system but also the Japanese ability to stick to a decision once it is made. It is both hard to get and to keep consensus in Germany.

Software Being Developed

The most interesting software is the feature-based design system mentioned above. It contains a feature-definition language that permits designers to make their own. The research engineer is just starting to address some important issues. One is how to tell the computer where the feature should be located. He is considering using geometric placement notation like "parallel" or "normal" to other surfaces or features. Another is tolerances, which he will root in these constraints. He can say "parallel" but he has no way to check if the designer or the computer achieved parallel. Third is parametric feature descriptions. There is as yet no integration between these parameters and the ACIS geometry engine. He agrees that a way needs to be found to chain parametric constraints and dependencies in technically sound ways, but none exists yet. That is, if one is not careful, one will get spaghetti code in the form of dependency chains that have unpredictable interconnections. I believe that some other researchers are using expert systems and truth maintenance in an effort to keep track of such inference chains.

It is important to note that Dassault Systemes (see "New CAD Software from Dassault Systems, Starting to Combine Design and Engineering," *ESNIB*, to appear) is already prototyping software that addresses some of the issues that this research engineer is just starting on. This is one of several cases where industry may be ahead in this field.

Another case is that of Prof. Kimura who abandoned research on new solid modelers and simply adopted ACIS.

Professor Wolfgang Beitz, Institut fur Maschinenkonstruktion, Technische Universitat Berlin

Professor Beitz is just coming to the end of a 10-year government-funded project to computerize the systematic design methods outlined in the well-known book coauthored with Professor Pahl.[1] Unfortunately, no funding is available to continue the research. Instead, Profs. Beitz and Krause will soon start a project about the use of telecommunications technology to support cooperative design. The project will expand the existing 100-terminal university computing network in Berlin.

The earlier years of the systematic design project included developing design methodologies for many typical engineering systems, such as pumps, transmissions, and motors. About two dozen Ph.D. theses contain this evolution. In addition, his work has developed the systematic approach and transferred it to the German standard VDI 2221, which he and Prof. Pahl helped to write. This standard describes a step-by-step procedure for designing things to meet specifications. More recently the work has turned toward software.

I spent part of a day with Prof. Beitz' research assistants as they demonstrated the systematic design software. Briefly, its goal is to mechanize VDI 2221. In principle this is an excellent process; it tries to make very careful links between functional requirements, functional descriptions of proposed solutions, physical embodiments of these solutions, and detailed design of the embodiments. The software is an attempt to show how this might be done with the aid of a computer. The software is described below.

First, it is necessary to say that not everyone in industry agrees that this approach will be useful in practice. The method seems to me to be too clean and unidirectional, lacking room for the essential dirtiness, conflict, backpedalling, and groping that usually characterize design. My hosts at both Volvo and Volkswagen ("Dramatic Reductions in Lead Time at Volvo Based on Restructuring the Design Process and Introducing Computers," *ESNIB*, to appear) stressed that design, especially concurrent design, has a strong element of conflict, sometimes requiring outside mediators to smooth things over! Professor Beitz says that the method is really best suited for teaching, where clear cases can be presented and students learn the ideal. The intellectual issue is an important one: how systematic can one afford to be if a design problem is quite new, or full of uncertainties about such things as fabrication or assembly methods? Does being more systematic help or hinder the design process? What kinds of design problems are best served by the systematic approach?

The research assistants are of two minds. Some agree that the method does not really support search and iteration, while the others defend it. The defenders say that without discipline, design becomes chaotic. They point to some recent industrial applications (one of which I report on below—Siemens), saying that without the systematic approach the problems could not have been solved.

The Siemens case is one where a former research assistant had used the systematic method in spirit. But his problem is to reform a chaotic design management situation for his new employer, not to establish or improve a functional design process. The assistant's education prepared him well for this task. Mr. Morelli of Telemachanique ("Systematic Design of Modular Products of Telemechanique," *ESNIB*, to appear) is doing the same thing for HIS employer.

The final word belongs to Prof. Beitz. He says that industry wants too much from the educational system, much as U.S. industry does: students who are ready to design when they graduate. He feels that education tells students what to do, but industry must teach them how to do it. Each industry or company is different; only the elements of the systematic approach are generic. The students carry the method to industry and are better prepared to tackle the specific problems they encounter.

He also says that although industry in Germany says it is using concurrent engineering, one should not believe what one hears. Even the automobile companies still have some high, hard walls. Concurrent engineering is a long way off because the walls are high and people are hard to change. From what I heard on later visits, I think he is

substantially correct. I heard much the same thing from Prof. Krause.

Software Being Developed

The software is intended to consist of an end-to-end design system for converting a set of requirements into a detailed design. It has been put together around an example problem, an emergency power unit. Another example is being worked up. The software consists of modules that someday will communicate with each other. The software comprises a solid modeler (CATIA), a user interface, several knowledge bases, some calculations, and several browsers. In its present state, the software is preliminary and is not completely integrated. Many desirable capabilities, such as linking one stage of systematic design to the next, have not been completed. Establishing these links, both in data and algorithms, would be a substantial achievement. Right now, people make the links. It is an open question whether such links can ever be made any other way, except on a case-by-case basis.

All other research laboratories that I visited where similar efforts were under way have taken basically the same approach to this most difficult problem: the software acts as an aid to the designer, who must make the important transitions himself.

The software consists of a series of modules that are used one at a time, apparently unidirectionally from the beginning. A program at the beginning permits requirements to be listed as text with modifiers and keywords. ("Provide backup energy source." "Convert energy from one form to another." And so on.) One can browse this list, searching for repetitions of the keywords in this or other task lists from other problems. A more structured final requirements list can be made up from this rather unstructured beginning. The final list can be arranged into sublists headed by titles such as "geometry" or "energy." Numerical requirements can be added, with modifiers such as "fixed" or "desired." These notations serve to remind the designer but have no computational impact.

The next stage is a product structure, consisting of elements that receive, process, and pass along such things as force, energy, and structural stability. These elements are represented as symbols and are linked to each other. (Energy flowing out of one element can flow into another, for example.) In the future, this will be the basis for a functional simulation, but right now it seems to be just a graphical display. This structure can be used as the basis for a search through a database for similar structures in past designs, or one of the blocks can be expanded into a substructure of similar elements.

The next stage comprises ways to link the combined requirements list and product structure to possible ways of realizing the product. I believe that there is no automatic way of creating this new list from the old one; a person seems to have done it in the demonstration I was shown. Again, the computer shows symbols representing physical items like bearings, gears, shaft couplings. Beneath each of these is a knowledge base (KB) describing its rules.

One of these KBs has been extensively developed—that for connecting shafts to hubs. A VDI for this has been implemented in the software. It gives rules for sizing shaft and hub diameters for shrink fit assembly, for example, including recommended tolerances. The recommendations are based on a detailed calculation that takes into account tolerances, friction coefficient, and safety factors. However, if the designer chooses tolerances that do not agree with those recommended, he must search manually for a consistent set. There is no automatic search support.

Another level of this software is the design management system. Here a chief designer is assumed who works from the functional requirements and product structure. This chief designer deals out tasks to other designers, utilizing the concept of a "function carrier" (FC). Ideally, the FC is a conceptual link between the desired function and a physical realization; in some cases it is an easy-to-identify thing like a bearing (carries the function of supporting the shaft). I did not get a clear impression of any other way to make this link. This gave me the feeling that this approach is useful for the "catalog component" method of design, but not for approaches that require several functions from the same item or cases where new items with unusual functions must be made up.

If this project were to obtain follow-on funding, there is the potential for a significant result, namely a system that would show how to link

functional, physical, geometric, and management aspects of a complex design process into an integrated activity governed by a standardized approach. No other laboratory with similar objectives visited on this tour has made any attempt to integrate design management with design engineering the way this project has.

Siemens Dynamowerk, Dr. Mario Schacht

Dr. Schacht got his Ph.D. from Prof. Beitz two years ago and joined Siemens right after school. This division of Siemens makes electrical generators and motors. Only the electrical ends are made here. Some are huge, more than 16 meters in diameter, and only a few are made each year. Midrange units are made in larger quantities and come in several types, for which a family of designs exists. The smallest units are made in relatively large numbers, and a predictable modular design approach can be used, along with a lot of CAD and some numerical control for flame cutting and welding the pieces together. But the largest machines are always specials. They contain an enormous amount of material, which drives their cost, which in turn drives the designers to think up new shapes every time to save material and meet the challenging specifications. By contrast, the cost of the smaller machines is driven by labor, so the effort goes into automation. So, says Dr. Schacht, three kinds of design are needed for the different size machines. "We always know the shapes of the small machines, but the shapes of the larger ones are different every time."

His job focuses on the largest ones. The designers deal with only a few each year; the need (habit?) to make up new shapes for what are, in fact, almost the same parts has created a hodgepodge of part names, part numbers, and data that are unusable for later designs. A way was needed to organize all of this, and Dr. Schacht has the perfect background for it. One would think that it would be enough to get the designers to use the same names each time, or to give out predefined sets of part numbers for the different types. This in fact has now been done. But in addition, Dr. Schacht has had to restructure the entire design process so that the generic elements of the generators are known to everyone and everyone thinks of the "same generator" when they are working. This means not only that everyone working on a given generator thinks of the same one, but that this one is "the same" in basic ways as all the past ones.

To accomplish this he has had to create a sort of standard design script, conceptualizing aspects of the design that even seasoned designers had not realized. He has drawn up design trees holding information such as "every generator has a shaft; every generator has a rotor shield that is either one piece or segmented depending on... If the rotor shield is segmented, then part A1 is eliminated and parts A2 - A5 are used..." On the wall in the office are large sheets of paper showing this structure in detail, representing months of work. This is quite in the spirit of his Professor's work. Reference 2 provides an overview of this approach.

SOME OBSERVATIONS

"Design" can be partitioned into many phases, including conceptualizing and detailing. Professor Beitz is trying to combine these two phases, while Prof. Krause is working more at the detail level, trying to strengthen the engineering aspects of geometry creation as well as the links between design and production. Both want to include search and conflict resolution, but neither have really made provisions for doing so.

Both groups are also primarily mechanical engineers seeking to apply computers to design as they see it. Software people are present only as facilitators, to keep the computers running. So the research stays focused on three-dimensional geometry. It still does not include much professional data structuring or manipulation, even though graduates like Dr. Schacht are doing just that (and could have done much of his work by using ICAD or WIZDOM, two commercial programs that permit geometry to be combined with rule bases). They also seem not to have a basis for approaching mechatronic problems, a topic that would require more sophisticated datastructures that could link several kinds of models together. The result is that their approach is resolutely bottom-up.

It is also interesting to hear their comments about expert systems. The older professors have no regard for them at all, believing that too much knowledge would have to be codified and put into them before they would be the least bit useful. Now, expert systems are just for simple rules and

design rule checking. The younger students have more faith, perhaps because they see no other way to gather all of the diverse knowledge required for concurrent engineering—"ten different sets of criteria for the designer to obey." But they do not see how hard it will be to build and verify such rulebases, nor how they will deal with the fact that the criteria conflict.

Only Prof. Krause had something interesting to say about expert systems, namely that design has some generic elements but technology planning is all specific rules. Would that distinction become less sharp if design and technology planning were more tightly integrated?

CONCLUSIONS

Professor Krause seems to be more in the mainstream of design research, looking at features and trying to link them to both geometric models and engineering requirements. Professor Beitz is sometimes regarded as a bit too idealistic, trying to capture something that is too difficult to capture, doing so by systematizing something that should be less constrained. Each one's research has limitations because of the lack of real collaboration with computer scientists.

Thus their approaches are mostly bottom-up, based on the engineering requirements in one way or another; they are not too sympathetic to approaches that claim to be able to design many kinds of engineered objects. Infrastructure issues have also, up to now, been of little interest.

Their work, both the parts that are successful and those that have yet to be, point to the following areas where more research is needed:

- understanding the relationships between constructing geometry and constructing an engineering description of an item (for example, when two surfaces are placed together, a force or a geometric reference will be transferred from one to the other: what are the size and direction of the force, or the direction of the reference? Are the surfaces strong enough or carefully enough toleranced for the intended purpose? etc.)

- extending the first item by separating engineering issues of function from those of manufacture and assembly and recognizing the latter's importance more explicitly. [Except for numerical control fabrication of single parts from their geometry (a capability that is now commercially available), research tends to focus on function, with attention only slowly shifting to other topics. Also, no strong coordination of these topics has entered the research stream yet. That is, how something functions, at several levels, is affected by how it is made and assembled, but this link has not shown up in research yet.]

- understanding how to move systematically from high-level functional descriptions of items to low-level specific descriptions, including listing completely what should be in a specification at each level. (All of the European and U.K. research I have seen so far requires the designer to make the essential connections; the software can be characterized as "inspired sketchpads.")

- learning how to include explicit recognition of conflict and revision in design. (Few researchers, even with industry experience, see the central nature of conflict and tradeoff in design. But these issues will rise in importance as concurrent engineering (CE) spreads, because CE brings in more criteria and these usually conflict.)

- learning how to describe design as a process and identifying several styles or metaphors for this process (sequential tasks with regular, planned feedbacks; overlapped tasks with feedforward and feedback between adjacent tasks, and so on) (My hosts at Rolls-Royce Aerospace — see "Object-Oriented CAD and Expert Blade Design at Rolls-Royce," *ESNIB*, to appear — said they had learned a lot about design from emulating manufacturing.)

REFERENCES

1. G. Pahl and W. Beitz, *Engineering Design* (Springer-Verlag, Berlin, 1984).

2. M. Schacht, "Methodische CAE-Vorarbeiten bei Variantenreichen Producten," (roughly: Systematic CAE Aids for High-Variety Products), to appear in *Konstruktion* **44** (1992).

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Manufacturing and Robotics Research at the Katholieke Universiteit Leuven, Belgium

by Daniel E. Whitney

KEYWORDS: mechatronics; stereolithography; EDM; automation; robot

INTRODUCTION

The Katholieke Universiteit Leuven (KUL) is the main technical university in Belgium. It has 26000 students; 2700 are in engineering and of these 560 are in mechanical engineering (ME). (For the first time, this is more students than are in electrical engineering). The teaching majors in ME are production engineering and management, energy conversion, and (new and attractive to students) mechatronics. Professor Joris de Schutter is in charge of mechatronics.

Research activities focus on production engineering, machine design and automation, energy conversion, applied mathematics (structural analysis, their strongest area, was founded by the late and famous Prof. Snoeys), biomechanics, graphics, CAD/CAM (computer-aided design/computer-aided manufacturing), robotics, structural dynamics, flexible automation, and industrial management (meaning production control). Research laboratories I visited included:

- acoustics and active noise suppression;
- mold design and direct NC (numerical control) production of molds;
- stereolithography, including attempts to find better polymers and ways to level the liquid faster to speed up the process;
- EDM (electrodischarge machining) methods, tool design, and studies of the fundamental process to create faster cutting and optimized computer control; and
- flexible automation, including flexible robot assembly systems.

A few words on each of these follow.

ACOUSTICS AND ACTIVE NOISE SUPPRESSION

This work began years ago as acoustic experiments and measurements, but recently they have attempted to make stronger links with analysis by using the skills of the applied mechanics division. Some European Community (EC) projects include searching for materials and designs for aircraft interiors that will transmit less perceived noise to passengers. Long-term projects exist on automobile dynamics and noise, and attempts are being made to update and improve finite-element models

from experimental data. A current project involves modeling both acoustic and fatigue behavior of composite aircraft panels. Because of the complexity of the structures they are trying to model, much of this work appears to be empirical despite efforts to systematize it.

MOLD DESIGN, STEREOLITHOGRAPHY, AND NC MOLD PRODUCTION

This work is in two parts, one being data-driven from a CAD (computer-aided design) model and the other being driven by digitizing a physical model, say of wood. Several problems have been pursued: getting error-free data [both IGES (International Graphics Exchange Standard) and DMIS (Dimensional Measurements Interchange Standard) cause problems], designing molds by using an expert system, and cutting molded shapes by using complex 5-axis machining so that the flank of the cutter follows the surface rather than the tip. Of some interest to me was the remark that coordinate measuring machine algorithms have been found to be weak here in Europe, just as they have in the U.S. Methods of automatically programming CMMs (coordinate measuring machines) sometimes give ill-conditioned algorithms. This laboratory has an EC project to improve this situation. Another weak area that has attracted their attention is the poor programming languages for stereolithography machines.

ELECTRODISCHARGE MACHINING

This study is looking at the fundamentals, including determining the effect of different pulse rates and pulse shapes. Apparently all of this is done empirically now, and little has been done to model it. The researchers have determined that even small details in the pulse shapes are important. Some economic modeling is also being done. The objective is to optimize the cutting rate without compromising tolerances.

ROBOTICS AND FLEXIBLE ASSEMBLY

Several projects are being and were done on high-speed robot control and sensing. I was also shown work on multijoint fingered hands driven by shape memory alloys. These joints appeared weak, but an attempt has been made to control the thermal behavior by using cooling oil. This allows the speed of relaxation to be made faster and thus more similar to the speed of contraction. The European Space Agency is funding some of this work. It was noted that the oil system is heavy and consumes energy, thereby robbing the shape memory system of most of its advantages, especially for space applications. No solution has been identified.

Another laboratory contains a flexible assembly cell on which real-time control work is being done. The aim is to develop schedulers for systems that can assemble a variety of parts or products. The main concerns here are technical since the processes are not very robust: how to detect errors, how to reallocate work to other stations when one stops, and so on. The economics of such systems is not being studied, and the lack of robustness seems to be a function of the student's skill. I have a feeling that some of this research would be better done by industry. Some good industrial research is reported in an article about Telemechanique, a French automation equipment manufacturer (D. Whitney, "Systematic Design of Modular Products at Telemechanique," *ESNIB*, to appear).

This laboratory is best known for its work on robot force feedback, but there is little support for this at present. My recent article, "Robotics in Theory, Robotics in Practice: 1992 IEEE Robotics and Automation Conference," (*ESNIB*, 92-05) describes this research.

I also saw some interesting work on robot filament winding for composite parts. The part demonstrated is T shaped, making winding of filaments nontrivial compared to simple cylindrical tanks. Considerable robot programming and development of a special hand were needed. This hand is able to periodically remove the net twist that develops in the filament as the result of the gyrations of the robot and the independently moving T while the filament is being laid down.

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Design Research at Cranfield Institute of Technology

by Daniel E. Whitney

KEYWORDS: artificial intelligence, high-speed communications, manufacturing, subsystem definitions, interface specifications features

INTRODUCTION

Cranfield Institute of Technology (CIT) is one of Europe's premier technological teaching and research institutes. It is located in Cranfield, Bedford, United Kingdom (U.K.), and is unusual in having on campus 27 separate research organizations [called Centers of Excellence (CoE)] and 12 commercial enterprises that formerly were CoEs. All once were departmental research laboratories and typically are staffed by former faculty and/or students. Most are small. Many retain direct connections to academic departments and provide research assistantships to Cranfield students.

Cranfield itself thus represents an interesting design; it contains on campus some of the elements of technology transfer and maintaining flows of information and people up and down the transfer path. It is more than a university, more than a technology park.

Cranfield participates in many EC-funded projects because of its excellence in aerospace engineering, artificial intelligence (AI), and CAD/CAM (computer-aided design/computer-aided manufacturing). This article discusses two of the projects and results from interviews with Professor Alan Morris, Head of the Aerospace Sciences Department. The projects have to do with using AI and high-speed communications to aid complex design processes: critiquing designs for manufacturability, and linking many designers so that they can pass subsystem definitions and interface specifications back and forth.

The topic of most interest concerned a new EC-sponsored project on collaborative design using broadband communication networks. The high speed of the network (144 MB) is not as interesting as the focus of the project, namely, trying to rationalize interfaces between complex engineering subsystems. One quickly discovers that some very basic questions need to be answered:

1. When a description of an object is handed across a boundary, exactly what information needs to be transmitted?

2. What constitutes an adequate description of the objects being handed across?

3. How should variability be described (variability includes tolerances and freedom for revision)?

4. How can really useful diagnostic messages be generated? "It doesn't fit" is not very helpful.

5. In the era of computerized design, with designers widely separated from each other, what will be the nature of the well-known interface control document (ICD)?

These questions could be applied to any designed object or system, not just to interfaces, which is why the project has broad interest and potential impact. The Navy impact is clear: every large system designed and built for the Navy involves prime contractors and many subcontractors and suppliers. The interface control document is a basic part of the development of these systems. It may seem like a humble, even bothersome, document, but Prof. Morris makes clear the technical opportunities available from making it the focus of a deep research project.

Prof. Alan Morris: Two Novel Design Research Projects

Professor Morris has specialized in the past on computational aerodynamics, but our topic of discussion was design and computer aids for design. He agrees that today industry leads in creating computer design tools, even though 20 years

ago one might have been able to get useful code from universities. For example, today no university can afford to produce commercially interesting finite-element codes.

Industry's offerings are nonetheless limited. No one commercial system does everything. He notes that inside Boeing one can find large CATIA installations as well as in-house software. I pointed out that it may depend on the program manager who, in many companies, controls the facilities budget for his program. In the case of the Boeing 777 aircraft, Boeing has chosen CATIA "because it comes from an aerospace company (Dassault Aircraft), which means that one can directly link surfaces to aerodynamic calculations," he says. He also believes that Boeing has added a large amount of its own software to CATIA. Another reason Boeing chose CATIA is that "electronic mockups" of interiors and interfaces to purchased items like engines can be made. Problems can be found early, different cockpit or passenger interiors can be compared, and communication between designers can be eased.

He contrasted Boeing and Dassault with the British aerospace industry which, he says, has not done its own research and development of design tools. British Aerospace was strong in this area 30 years ago, but now they buy commercial software. Dassault apparently felt, like the Japanese companies I visited last summer,[1] that it could not buy what it needed.

Before the age of computers, stress specialists participated early in the design process, according to Prof. Morris. When computers arrived, they were able to analyze only bits and pieces of the airplane, so the stress people waited until detail design was well under way before doing their evaluations. When they found problems, the design was seriously delayed. Dassault now has a computer system that is geared to permitting rough stress calculations and identifying places in need of evaluation early in the design process. Enough computer power is now available to look at the whole plane, and specialists "now have their proper role—advising at an early stage."

Dassault has also done a good job of linking geometry, aerodynamics, and flight control software, thereby permitting several varied parts of the design to be done in a coordinated way.

Professor Morris also had interesting comments to make about the history of concurrent engineering in aerospace. The walls came down 20 years ago when carbon fiber composites began to be used. The new material presented a wide range of problems: how should one design, analyze, manufacture, and certify aerospace structures? These issues concern all the major interested parties, including government (because it contains the regulatory agencies). Everyone has to work together. When aluminum was the only material, the designer was king and everyone did what he said.

Then he drew my attention to two EC projects he is involved in that are quite unlike conventional CAD/CAM/CAE.

1. EC Project on Computerized Design Critics

This project is called IKADE. Several universities and companies in EC countries are involved. The goal is to develop a design critique system that can help a designer determine basic manufacturability issues. Apparently the goals are fairly basic: is there a machine in the shop that can make this workpiece, or this feature on this workpiece?

It appears that the researchers originally thought this was a fairly meaty problem, but they have now realized that commercially available software packages can handle it, at least at the level they are aspiring to. Two packages have been chosen, leading to some confusion in his opinion but perhaps a nice side-by-side comparison. The two are ICAD and WIZDOM, both U.S. products with quite similar capabilities. They permit geometry to be entered and rule bases to be constructed. As a result, simple design protocols can be built that capture repetitive decisions and capabilities. An example is "If load on beam X exceeds Y then use steel." General Electric (GE, U.S.) has spent several years packaging such problems into software. It calls them "purchase order engineering," meaning modifying existing designs to meet new customer specifications. According to GE, 85% of its design effort corporation-wide falls into this category.

The interesting point here is Prof. Morris' opinion that academia could not easily have created the capability that ICAD and WIZDOM have.

Yet it should be noted, as above, that the aspirations of this project are not great. A more ambitious project could quite possibly have exceeded any commercial package. This opinion is based on papers given at last year's International Conference on Artificial Intelligence. This conference contained a special session on AI applications, including several design aids. These were quite sophisticated and were not likely to be within the capabilities of the commercial software.

Two companies are participating in this project: Lucas Engineering of the U.K. and Roneo, a Spanish furniture maker. Lucas makes highly engineered products, whereas Roneo's desks and filing cabinets comprise standard components, simple shapes, low mechanical stresses, easy tolerances, and so on. Morris says that he and others worry that they have been biased in their work by the simplicity of the furniture.

I raised the question of how much/how detailed geometry information is needed for some DFM studies and when is some nongeometric information of more importance. He felt, as expected, that it depends on the product: aircraft surface shapes are quite important, and small changes can render them unmanufacturable by available machines. This is not true of the desks, whose shapes are so simple and noncritical that almost anything the designers can think up can be made in the existing shop.

By contrast, in Japan I saw the camera companies going through an upheaval as they tried to adjust to cameras with sculptured surface exteriors. The car companies have had 20 years to develop software and methods for this kind of design, but the camera companies have had to climb the learning curve in only 3 years. This shows how a change in product style or production technology can invalidate existing design methods and software, as well as existing production equipment. When might sculptured-surface office furniture become stylish, and what will happen to design then? The Spanish may be the ones to do it, too.

Despite the strong AI component in this project, Prof. Morris is not optimistic about the ability of AI to significantly aid the design process. They are thinking about how to add it, but at the moment he is more intrigued by the idea that vivid graphic displays can strongly couple the human expert to the problem, permitting real synergy and progress on a design. Stacks of printouts contain the same information in principle but can't be interpreted.

2. EC Project on Broadband Communication

The other project Morris described, called EDID, is new and much more technically challenging. It is about distributed design in the anticipated future environment of really high-speed communication:

> How will design be done by groups of geographically separated designers who have access to 114 megabit/s communications?

Several universities and companies are involved, including IBM U.K., British Telcom, Alcatel, and Aerospatiale. The project has focused on an interesting subset of design, namely checking interfaces between designed elements or subassemblies, detecting and identifying mismatches, and negotiating resolution of the mismatches.

The project is funded by RACE (Research and Development in Advanced Communication Technologies in Europe). The subject is broadband communication. (He says the EC has an amazing array of acronymed programs. This one is not part of BRITE or ESPRIT.) It originated from a rather vague call for proposals recognizing the impending availability of broadband communication, asking for proposals on how to get companies and universities to think about what it would mean and how to use it. One gets money from these organizations by putting consortia together and proposing specific things that read on the RFP. Concurrent Engineering and Distributed Design seemed like an obvious target.

This is a fascinating project because it raises several basic issues that apply to much more general design problems:

1. When a description of an object is handed across a boundary, how should the recipients be prepared for what they are to receive, what should they expect in the way of technical content and information structure, how are they to find the information they need, etc?

2. Regarding the objects themselves, what constitutes an adequate description?

   - geometry? pictures? simulations?
   - geometry plus some sort of functional description?
   - "features?" variability? (see next item)

3. How should variability be described (variability includes how the interface might deviate within tolerances as well as how it might be altered within specifications should a mismatch be detected).

This list could be applied to any designed object or system, not just to interfaces, which is why the project has broad interest and potential impact. It also brings to the surface some questions raised above: is geometry the main kind of design data, and if not, then what else is needed and how can it help? Virtually all existing CAD, CAM, and CAE deal exclusively with geometry.

Professor Morris used hydraulic pipes as an example. Suppose pipes must be joined across the interface and suppose positioning errors between the pipes are to be detected. One wants to be able to say more than "they don't fit up." One wants to be able to suggest a fix, but to do so requires other information. For example, if the errors are lateral, are the pipes flexible enough that the errors can be fixed just by shifting them sideways a little? If the errors are longitudinal, are strain relief bends designed into the pipes that can be flexed a little? On which side of the interface is it easier to put these bends? Is the pressure in these pipes so large that no flexing should be attempted? Etc.

At present, there are two ways of handling interface problems: the physical mockup and the interface control document (ICD). The mockup is satisfactory for nondistributed design when there is plenty of time and money, but these ground rules are withering away. The ICD is a really huge document that is administered by a prime contractor who resolves all conflicts, not only between itself and subcontractors but also between subcontractors. Resolutions take a long time and require very knowledgeable people who understand the relationships between subassemblies and the system-wide impacts of suggested resolutions.

The project as it is presently shaping up seems to assume that both the ICD and the resolving role of the prime contractor can be replaced by a proper computer aid, high-speed communications, participation of the designers, and design protocols. In particular, a decomposability assumption seems to have been made, namely, that each interface mismatch can be resolved across that interface independently, without reference to other interfaces or the internals of the system as a whole.

It is a matter of conjecture whether this assumption is true or not, in my opinion, and I did not detect that testing it was part of the project. However, he notes that Aerospatiale originally argued that its usual mode of operation should be maintained in the new setup: all interface discussions are held one-on-one, with Aerospatiale being one of the participants. Thus no subcontractors can talk directly to each other. This apparently is the "French style." He contrasted this to the U.K. style, where any box that can really be isolated (he cited avionics as a candidate) can be dealt with by the subcontractors themselves. In this project, a compromise has been reached, in which any pairs can talk as long as Aerospatiale joins in.

Since the approach is young, the approach is still evolving. As Prof. Morris describes it, it fits the mold of an object-oriented database in which each subassembly or interface specification is an object with a set of attribute slots. (No implementation has begun and, in fact, the basic issues are still being explored.) Things that must be slotted include the items listed above plus some sense of "stiffness": some things are negotiable while others are not, or not unless certain identified costs are acknowledged, such as money, time, or performance. If such information is provided, it opens up the typically closed ICD-dominated situation in which the prime contractor often acts dictatorially. Morris anticipates that designers will enter the negotiation directly, enhancing their role and making the process more creative and efficient. Of course, people do not always make their negotiating positions known, so either the system would require some changes in behavior or it might not work.

The project represents a big step forward in sophistication in several areas, not just in ICDs. The EC sponsors have come to realize very quickly

that merely transmitting geometry or pictures will not solve the problem. This means that they are climbing the learning curve very fast compared to many others who confront similar problems. Many new issues are emerging. He agrees that these problems go way beyond broadband communications, but he was reluctant to say that broadband communications was just a vehicle for what they were really interested—just that he was quite aware that other research goals would be served.

The companies, too, are finding their preconceptions under attack. At first they thought the result of the project would simply be an "electronic ICD." They do not want to upset their current methods very much—they do work, after all!

CREATE Ltd

While at Cranfield I also visited CREATE Ltd. This is a 20-person consulting company that spun off from Cranfield Institute of Technology in 1979; it was 1 of about 12 such spinoffs that evolved from Centers of Excellence on campus. Other centers are still in operation.

At present, more than 25 other Centers of Excellence. CREATE was purely a design consultant until 3 years ago when the current deputy managing director, Colin MacMillan, took over. His background is in manufacturing, and he extended the firm's reach to include making factory automation equipment. However, few clients with design problems ask CREATE to design their manufacturing equipment. "Clients usually know how to make their product." Companies come to them when they have run out of ways to solve a hard problem, or when they want a fresh look.

My visit here pointed up the challenges faced by a small company that sees different engineering and design problems regularly rather than repeats of the same problem. There is little commercial computer support for them beyond commodity CAD drafting and a few finite-element codes. They get by on 386 personal computers, operate on their wits and ability to formulate a quick but accurate mathematical model, make drawings and, possibly, numerical-control (NC) tapes, and build prototypes. Until now they have not been able to field a product of their own design or conception. "We are totally customer-driven." Also, they work to fixed price quotes.

CONCLUSIONS AND DISCUSSION

The design research activities described by Prof. Morris, especially the one on interfaces, suggest several lines of research:

- do we know what an adequate description of a product (equivalently, a designed item) is? That is, to what degree must the description hold information that supports or is even about the design process itself rather than just about the product—how it will be made and used, and so on? This is a new wrinkle, in my opinion.

- do we know the difference between "communication" as a supporting activity and communication as an active element in the design process? For example, the EDID folks are depending on negotiation to be facilitated by high-speed communication. But it is known that negotiation is central to concurrent engineering, and that skilled negotiators have several agendas and tend to hold back information during the negotiation process. An important reason for holding back is that the ability to meet a specification may depend on the availability of design resources such as people or test gear, rather than just on ingenuity or the state of engineering knowledge. "I'll solve your heat flow problem if you give me Joe from your group" is a typical negotiating position.

- do we really know what to expect of artificial intelligence as an aid to the design process? This question is only tangential to this report, but it is stronger in other reports. (See especially articles on design research in Berlin and several U.K. universities.) That is, AI holds a lot of promise, but we need to recognize the current status: only simple rule checking seems feasible now; the amount of serious and deep knowledge that needs to be codified is huge; deciding how to codify and interlink it may be equivalent to repackaging all of engineering. When people attempt something serious, such as AI that suggests an improvement to a design or converts a high-level functional specification into a lower level

physical implementation, only the most trivial realizations are achieved.

• do we appreciate the strong links between the way design processes work and the way businesses operate? The French and U.K. styles of dealing with subcontractors and ICDs illustrate the point. The Japanese car industry provides another regional contrast. Recent research shows that Japanese car builders have cultivated a multilevel supplier industry, arranging long-term contracts, flowing design and manufacturing technology down, and encouraging lower level suppliers to build and nurture their own chains.[2] Rapid, two-way flow of design data, costs, constraints, and production requirements is a strong ingredient of such a system. Thus what we think of as "design tools," the familiar finite-element packages or solid modelers, merely scratch the surface of the kind of tools peoplewill need in the future. The example also shows that we must begin thinking about designing infrastructures to support concurrent design and distributed design, equipping these infrastructures with the right decision tools.

An interesting example of such infrastructure design can be found in MOSIS, the DARPA-sponsored electronic network that permits custom integrated circuits (ICs) to be made to order. A standard design language was created by Carver Mead and Lynn Conway[3] that permitted designs to be described and communicated to a family of vendors. These vendors would then piggyback the ICs onto their existing production activities. But there was a hitch in this process that required human intervention and judgement.[4] This was the requirement to check the designs to be sure they conformed to a set of design rules and to sort the designs according the rules they obeyed in order to match them to the capabilities of the vendors. This sorting and matching is part of what DARPA has come to call *brokering* in its new application-specific electronic module (ASEM) program. The implication is that even the most apparently paperless and systematic design-build process needs help at critical points.

REFERENCES

1. D. E. Whitney, "State of the Art in Japanese Computer-Aided Design Methodologies for Mechanical Products - Industrial Practice and University Research," ONR *Asian Office Scientific Information Bulletin* **17**(l), 89-112 (1992).

2. James P. Womack, Daniel T. Jones, and Daniel Roos, *The Machine That Changed the World* (MIT Press, Cambridge, MA, 1990).

3. Carver Mead and Lynn Conway, *Introduction to VLSI Systems* (Addison-Wesley, Reading, MA, 1980).

4. Danny Cohen (Information Sciences Institute of Rand Corp.) presentation on history of MOSIS to DARPA Design Researchers' Workshop, Salt Lake City, Sept. 28, 1992.

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Sophisticated Concurrent Engineering Without Computers: Ecole Nationale Superieure des Arts et Metiers, Paris

by Daniel E. Whitney

KEYWORDS: concurrent engineering; product development strategy; semantic shape diagram; conceptual level; functional elements

SUMMARY

The Ecole Nationale Superieure des Arts et Metiers (ENSAM) Laboratory for New Product Concepts is an interesting mix of research, teaching, continuing education, and industrial consulting. Without the aid of fancy computer tools, this group has carefully and pragmatically elaborated a product development strategy that is considerably richer than typical concurrent engineering (CE) methods. Products are described at three levels (architecture, minimal parts list, and full parts list), and roles for each of the actors in a CE process (marketer, fabricator, assembler, purchasing agent, etc.) are spelled out for each level. This is considerably more sophisticated than just forming teams and letting them figure out what to do.

BACKGROUND

ENSAM is an Ecole Superieure, which means that it is dedicated more toward teaching and less toward research than a university. In this sense it is like a polytechnic in the United Kingdom (U.K.). This article describes the Laboratoire Conception de Produits Nouveaux (New Products Development Laboratory). The director of the laboratory is Professor Robert Duchamp. Because he was absent the day I visited, this article is based on discussions with Ph.D. candidate M. Marc Le Coq. The laboratory itself is a combination of teaching site, research laboratory, and industrial consulting company. All the activities center on design of new products. In some cases this involves creating concepts, while in others laboratory evaluations and prototypes are produced. The customers include private industry and the French government. The laboratory openly advertises its services and has booths at trade and technology fairs. It also holds its own seminars and laboratory open-houses. Most of its glossy literature is in English, German, and French in an effort to attract European customers and students.

APPROACH

The students participate in and do their research as part of the consulting activities. In addition to the students, several full-time engineering staff are involved in mechanical design, software, and construction of apparatus.

Examples of specific products the laboratory has worked on include:

- a pump for Third World countries that runs on solar energy (they discovered that people in such countries don't understand how to maintain this kind of equipment, a factor they had not taken into account when designing it);
- applications of water-jet cutting: composites, chocolates (for composites, abrasives can be added to the water to help it cut but for food you cannot do this, so they added ice crystals—a nice idea). They invited artists to try designing innovative things from the composites; one came up with one-piece folded armchairs (Fig. 1);
- a new kind of large-screen display based on optical fibers (it was not a good concept—very hard to make, and no one is interested);

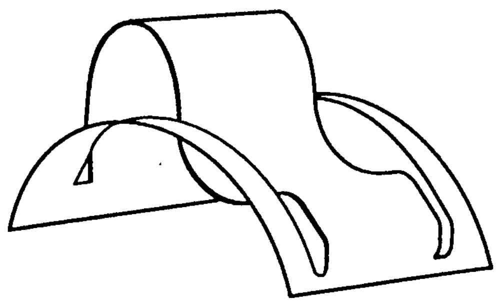

Fig. 1. Chain made from laser-cut composite material

- a coffee maker for small hotel restaurants being developed for a small business that has government funds for the project;
- a computerized training aid for operators of complex offset printing presses (the issue is to get four or five colors to line up and look right, a skill that normally takes several years to acquire; in this case, high-quality color computer graphics, a mouse-menu interface, and an expert system have been combined into a nice training tool).

In the past they worked on robot assembly, but the demand for this from industry has fallen to zero.

DEVELOPMENT OF DESIGN METHODOLOGIES

On top of the consulting and teaching activity is an effort to generalize what they have learned into procedures for carrying out new product development and CE. The procedures they have followed up to now constitute a manual methodology rather than computer tools. The main steps in the process that they describe are the familiar ones of identifying the need, converting need statements into function statements, searching for possible implementations, choosing one, testing and prototyping, etc. In this regard their work sounds like that of Prof. Beitz and others [see "Design Research and an Industrial Application of Systematic Design Metholodologies," *ESNIB*, this issue].

However, Prof. Beitz takes a heavily engineering-oriented approach whereas the ENSAM people work at a more conceptual level and are not as technically focused. Interesting aspects of their methods include making a semantic characteristics list to describe a product, making diagrams that show how each part or assembly satisfies each requirement, and looking at a product at different levels called "minimal parts," "architecture," and "individual parts."

Figure 2 is an example "semantic shape" diagram. One attempts to describe the product at the concept stage on a scale from -3 to 3 according to each of the characteristics (ergonomic vs hard to use, functional vs stylish, attractive vs repulsive, intuitive vs rational, etc.). Market-sensitive people apparently fill out this diagram first. Later, when concepts or prototypes are ready, they are graded against the original diagram. The contrasts are immediately visible in the different shapes of the profiles.

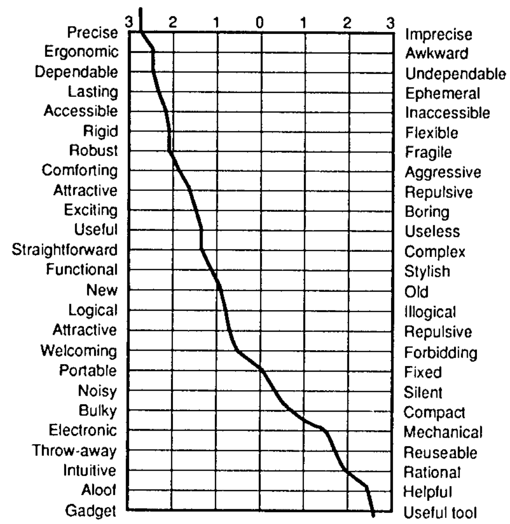

Fig. 2. "Semantic shape"

Figure 3 is an example of a "functional schedule of conditions," a diagram relating parts to functions. The product in this case is a gas mask designed for the French Ministry of Defense. A key issue here was utilization of totally new materials, one for the opaque body and the other for the transparent visor that could be injection-molded at the same time. The Materials Laboratory at ENSAM developed the materials first, and the New Products Development Laboratory got the follow-on contract to design the mask itself. The items listed are:

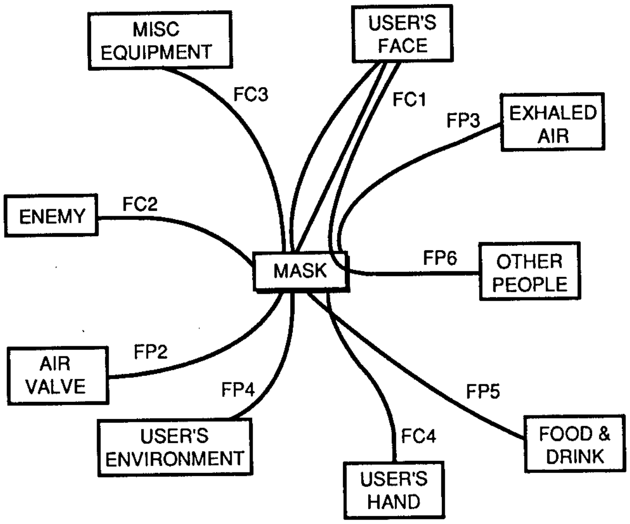

Fig. 3. Functional schedule of conditions (FP, relates mask to user; FC relates mask to its own environment)

- FP1: protect user's face from the outside
- FP2: permit user to breathe
- FP3: vent exhaled air to the outside
- FP4: permit user to see environment
- FP5: permit user to feed himself
- FP6: permit user to communicate
- FC1: adapt itself to user's face
- FC2: resist attack
- FC3: be compatible with use of miscellaneous equipment
- FC4: be adaptable to user's hand.

The items in the boxes are, for example: user's face, expired air, consume liquids, and the central box is labeled Mask (figure is from Ref. 1).

The Ph.D. work of M. Le Coq attempts to tie all of this together by laying out the elements of a systematic product design method. The paper[2] he (Le Coq) gave me is in French, but I am able to understand most of it. Every product development project has four components:

1. The product concept itself: this is a clear statement of the first idea of how the needs might be met, stated in such a way that all the people who must participate in the design process can understand it.
2. The procedure: this is a statement of the actions that the design team must carry out in order to design the product.
3. The structure: this tells the designers how they must interact with each other in carrying out the procedure. Two different types of structure are identified: the multidisciplinary team method and the series of experts method.
4. The tools: these comprise engineering, computers, etc., plus their software and methods.

The procedure operates at three conceptual levels: the minimal set of parts or elements that can satisfy the requirements, an architecture (spatial arrangement and physical connections) that links those parts, and all the individual parts in a complete design. These are pursued in that order. The main job of the designer is to think up architectures and their minimal parts, while the engineer must determine the flows of energy, fluids, heat, stress, etc., between these minimal parts. In the best of situations, the work is carried out by a designer-engineer who can work at all levels.

The most interesting part of this is a chart (Fig. 4), which shows how each of the players in a multidisciplinary design team might see the minimal parts, the architecture, and the individual parts. For example, the assembly person would look at the minimal parts from the point of view of trying to standardize them and their required assembly processes. This person would look at the architecture from the point of view of assembly sequences and process optimization. Finally he would look at individual parts to see how to speed up their assembly and lower the cost of doing so on an individual part basis.

CONCLUSIONS

Work at the Ecole Nationale Superieure des Arts et Metiers, Paris, is not at the technical level usually found at universities. However, it has the merit of being derived from actual experience in designing products for industrial customers, plus trying to teach the method to the customers for their own use. Thus it reflects a lot of careful thinking without being encumbered by attempts to do great things on a computer. Considerable structure and detail has been provided on what a good design process should consist of beyond good

	Indispensable Parts	Architecture	Parts
Marketing, sales	Image, impact of technology, sale price	Market niche or level, diversity, differentiation, cost	Finish, cost, market niche or level
Design, styling	Concept choice, technology	Market niche, image, uses	Appearance, shape, visual and tactile aspects
Ergonomics	Scenarios for use	Scenarios for use, macro actions	Micro actions, visual and tactile aspects
Design office	Technology, choice and realization of actions and flows of energy and information	Respect for constraints on the flows based on the concept requirements	Optimization of flows, shapes, fastenings, and connections
Fabrication	Technology and standardization of processes	Process choice, complexity of parts	Process optimization
Assembly	Technology and standardization of processes	Choice and optimization of processes, trajectories, tools...	Optimization and realizability of cycle times, automation
Testing	Technology and standardization of tests	Testing scenarios and strategies, creation of functional subassemblies	Interfaces, system connections, repairs
Maintenance	Strategy, cost and exchange of parts, warranties	Accessibility for diagnosis and repair, changes to the system	Ease of removal and replacement, special tools
Purchasing	Policy, constraints on suppliers, make-buy decisions		
Recycling	Standards and constraints (toxicity...)	Homogeneity of materials, access to dangerous elements	Material choice, removability, disposability

Fig. 4. Views of the major roles in product conception by each of the members of a multidisciplinary design team

words like "break the design up into functional elements" and so on.

The intellectual problem is whether even this level of decomposition has enough substance to be applicable to a wide variety of products. The hope is that more detail will result in an explicit process that can be followed in many cases. The downside is that as one looks in more detail at the products themselves, one finds that the process must be significantly altered, even rebuilt, in order to meet the technical content inherent in the product. Thus the effort to describe the generic design process in more detail may not be rewarded because the generic details it comprises will not be relevant to the products. We need to generate and compare more of these candidate design processes and use

them on more products before we can see if a pattern emerges. This is one of the more important generic research issues in design today.

REFERENCES

1. Ameziane Aoussat, Patrick Truchot, and Robert Duchamp, "Training for Product Innovation," a descriptive handout of the Product Innovation Department at ENSAM

2. Marc Le Coq, "La R&D dans Une Logique Produit: Contribution a la Reduction des Delais de Conception," working paper, ENSAM Product Innovation Department

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Chemistry

Max Planck Society Working Group on Complex Catalysis—Rostock

by C.T. Owens, who was head of the National Science Foundation's Europe Office from mid-1990 to mid-1992. He is currently working on detail to the Department of State as Senior Advisor in the Oceans and International Environmental and Scientific Affairs Bureau, and in the Politico-Military Affairs Bureau.

KEYWORDS: research equipment; catalysts; asymmetric reduction; physiological action; NMR

[Note: This visit was made in July 1992. With the exception of the comment in the final paragraph, the report reflects the viewpoint of the person interviewed.]

THE WORKING GROUP

The Max Planck Society (MPG) has set up a Working Group on Complex Catalysis. The Director of the Working Group is Professor G. Oehme. This Working Group is a successor to the Institute for Organic Catalysis, which was an institute of the now-defunct Academy of Sciences of the former German Democratic Republic (GDR). Support for the Working Group comes from the länder of Mecklenburg-Vorpommern as well as the MPG. The MPG support will continue for five years, after which some other administrative arrangement will be found. Some possibilities include combination with other groups to form a "blue list" institute (funded half by the federal government and half by the länder) or becoming an institute of the University of Rostock. Currently, the Working Group cooperates closely with the university but is administratively separate. Professor Oehme has a faculty appointment and teaches at the university.

The old Institute had a staff of 78 researchers, technical, and support staff. Today the Working Group is down to a staff of 50, and further reductions will be effected in time. Reductions will come especially from the support staff, currently 27 of the 50 employees. This will mean that the Working Group will have to have a different structure and character to its work—obtaining from

outside suppliers many services previously supplied from within. The research program of the Working Group will, however, remain focused on homogeneous catalysis and on transitional phase materials.

About 38% of the resources of the Institute from which this Working Group has been formed were devoted to industrial work. Some of the basic research had industry support as well. The work of the former Institute was very much driven by the needs of the GDR chemical industry, but it also had freedom to do basic research. In the last years of the DDR, the university was also required to have ever-closer connections to industry, and this was not very good for the university.

The lines of fundamental research, many of which continue today, included:

- immobilization of optically active, homogeneous catalysts for hydrogenation reactions;
- preparation of unusual amino acids by asymmetric hydrogenation;
- enantioselective C-C-coupling reactions;
- course of enantioselective catalytic reactions in colloidal phases;
- photochemically assisted cocyclizations of acetylene and nitriles to pyridine derivatives catalyzed by cobalt(I)-complexes;
- structure-reactivity relations of nickel-acetylene complexes used as catalysts for cyclization of substituted acetylenes;
- synthesis of chiral phases for GC and HPLC analyses; and
- development of highly active Ziegler-Natta catalysts for ethylene polymerization.

Current research also includes work on asymmetric reduction of ketones and aminoketones via physiological action of chiral amino alcohols, on using homogeneous hydrogenation to chemically create optically active amino acids, and on selective synthesis in organic chemistry for the production of optically active catalysts, especially rhodium phosphene.

Analytical equipment at the Working Group is shared with the University of Rostock's Department of Chemistry. The University is due to receive a 250 MHz NMR and a 300 MHz NMR in the near future, and MPG is purchasing a high-resolution 400 MHz NMR for the Working Group. Experimental equipment available to the Working Group today includes:

- mass spectrometry
- infrared spectrometry
- 80 MHz NMR
- gas chromatography (Hewlett-Packard 5890 and 5880 A)
- high-pressure liquid chromatography.

NSF/Europe Comment: Professor Oehme would welcome collaboration with American researchers interested in the work of the Working Group. There is still a great deal of adjustment in store for the group in the coming months beyond the personnel changes mentioned above. The facilities of the group are centrally located in Rostock in quarters that will certainly be getting some needed repairs. First-class research equipment is coming in and replacing and/or augmenting the capabilities of existing gear. The MPG can provide everything that a researcher could want to have. However, it probably will be a year or 18 months before optimum conditions exist for the planned research of this new Working Group.

Computer Science

Flexible Harnessing of Computer Processing

by Dr. Jeff Kramer, Department of Computing, Imperial College of Science, Technology and Medicine, London

KEYWORDS: configurable distributed systems; component interfaces; parallelism; allocation; protocols

THE TOPIC

With the proliferation of computer systems in all walks of life, the ability to manage their power while maintaining flexibility is one of the biggest challenges of this decade. Distributed computing offers one of the most promising approaches for computer processing. The users of computers, the information they require and provide, and the applications themselves all tend to be distributed. In addition, distributed computing offers advantages in its potential for improving availability and reliability through replication; response and performance through locality and parallelism; and extensibility and scalability through modularity. The challenge is to harness this flexibility to configure distributed systems to suit the tasks at hand, whatever they are.

The International Workshop on Configurable Distributed Systems (IWCDS) was held 25-27 March 1992, at the Imperial College of Science, Technology and Medicine (London, U.K.). It was concerned with methods, tools, and techniques for configuring (structuring) and managing the software for distributed applications. The software configuration of a distributed system is usually described in terms of instances of software components, binding the components together, and allocating components to a hardware configuration. Reconfiguration is required to recover from failures and to permit the system to evolve to include new functionality or new technology. Large systems require dynamic reconfiguration to support dynamic change without shutting down the complete system.

These requirements raise many issues:

- What form should software components (or objects) take?
- What interfaces should they provide and how should they interact?
- How and when should they be bound together?
- How should heterogeneous components interact?
- What language and execution mechanisms do we need to describe, support, and manage system configuration and reconfiguration?
- How should we design systems such that they support rather than inhibit change by reconfiguration?
- What decomposition criteria should be used to produce reconfigurable components?
- What change protocols are necessary to support dynamic reconfiguration?
- How should we deal with failures?
- What allocation strategies should we use to improve performance?

Some possible answers have been suggested. Components should, for instance, be context-

independent to facilitate their use in different configurations. Component composition provides a powerful means for constructing more complex components. In fact, the ability to compose systems from component instances seems to be the underlying principle for system (re)configuration. Similarly, composition of component behaviors, timing, failure characteristics, and performance should go hand in hand with component composition to provide system characteristics.

Component interfaces should explicitly describe all permissible interactions, including failure modes. For the greatest flexibility, bindings should be possible at any time; this does however complicate the visibility and management of a system configuration. Components using atomic transactions seem to possess the independence necessary for dynamic reconfiguration, but is atomicity necessary?

Configuration languages seem to provide a viable means for describing, constructing, and managing system structure, but should they describe (initial) static structures or dynamic ones, permit only programmed change or any arbitrary change, and should they be purely declarative or imperative?

The workshop program discussed these and other associated issues and tried to assess the suggested solutions and proposals. An important part of the panel discussion was future directions in configurable distributed systems.

THE PROGRAM

IWCDS was designed to provide a forum for researchers in configurable distributed systems (CDS) to present their results and exchange ideas and experience. In contrast to large international conferences, the purpose of this workshop was to encourage discussion. For this reason, presentations were kept short, leaving ample time for questions and discussion.

Papers were submitted from researchers throughout the world: the U.S., U.K., Canada, France, Germany, Italy, Brazil, Israel, and South Africa. After a strict refereeing process, 25 papers were selected. These were organized into seven sessions:

Session 1: Application Design
Session 2: Languages I
Session 3: Languages II
Session 4: Dynamic Configuration
Session 5: Configuration Support
Session 6: Performance and Process Allocation
Session 7: Management

In addition, an invited opening address described reconfiguration in the presence of failures. The closing session consisted of a panel of international experts to discuss the implications of the work presented at the workshop and to provide a view of the future trends and research issues. The presented papers are briefly described below.

OPENING ADDRESS

The invited speaker, Flaviu Cristian, described his work on "Automatic Reconfiguration in the Presence of Failures." He described the need for, and design of, an availability management service that is responsible for ensuring that the services implemented by a distributed system remain available to clients despite failures. The service is provided by a number of servers, which are the units of failure and growth. A loose synchronization policy permits the use of primary and backup servers managed by an availability manager in each host. The operations supported by an availability manager include start and stop service, add and remove host, and the ability to promote and start backups. The availability managers are distributed on the system hosts; they cooperate to reconfigure the system to ensure a particular level of service. The approach uses underlying layers for clock synchronization, broadcast, and membership protocols. Other approaches to the provision of available services were also presented and are described later.

APPLICATION DESIGN

Three papers focused on design aspects. Although all three produce designs as some form of interacting components or objects, the approaches and characteristics of the objects and interactions

differ. Both Gomaa and Simpson (see below) produce designs that emphasize the structural configuration of the application.

Hassan Gomaa presented his approach to "Structuring and Configuring Distributed Applications." This is based on domain modelling, which is analogous to producing a generic configuration architecture for a family of distributed systems. The approach provides criteria and heuristics for system decomposition and structuring and is illustrated by an example from factory automation. The underlying model is one of concurrent objects communicating by messages.

Atomic actions operating on persistent objects was the model adopted by Stuart Wheater and Daniel McCue in their paper, "Configuring Distributed Applications Using Object Decomposition in an Atomic Action Environment." The approach advocated for application design is that appropriate selection of the object decomposition can be used to configure the level of concurrency and distribution and hence the availability and performance of the application. This work uses the Arjuna system.

Hugo Simpson described his design approach in "Real Time Networks in Configurable Distributed Systems." In contrast to the two preceding models, this approach uses shared data communication, with minimal synchronization and timing interference. The overall approach uses the MASCOT approach for application design and configuration.

LANGUAGES FOR CONFIGURING DISTRIBUTED APPLICATIONS

Languages and their associated environments for describing, constructing, and managing distributed applications were presented in these sessions. To some extent, all of the papers adopted the general configuration programming approach of separating the language for describing program structure (configuration model) from that used for component programming (computation model). Many focus on or include the problem of describing changes in configuration structure that may occur dynamically during execution. During these sessions, a number of interesting discussions took place comparing declarative against procedural configuration languages, and arguing whether configuration languages should be separate from or an extension of the component programming language.

Ian Guffick and Gordon Blair presented "Building Configurable Distributed Systems Using the Kitara Object Oriented Language." This adopts the use of multiple tuple spaces for object communication, and argues that these provide the decoupling necessary to support system configuration and reconfiguration.

Markus Endler and Wei described their work on "Programming Generic Dynamic Reconfigurations for Distributed Applications" by using a language called Gerel. This extends the REX structural configuration language, DARWIN, by using a logic-based object selection mechanism to describe both general configuration changes and their preconditions.

Ian Sommerville and Ronnie Thomson described their work on "Configuration Specification Using a System Structure Language" called SySL, which permits component attributes, structures, and configuration constraints to be described.

Terry Coatta and Gerald Neufeld focused on the use of configuration constraints specified in first-order predicate logic. "Configuration Management via Constraint Programming" proposes using constraints to describe the acceptable states and initiating reconfiguration actions when constraints are violated.

The DARWIN configuration language and associated approach was described in "Structuring Parallel and Distributed Programs," by Jeff Magee, Naranker Dulay, and Jeff Kramer. In addition to expressing static software and hardware structures, DARWIN can be used to express structures that change dynamically. The configuration language has no state; it uses programmed components to decide when to initiate change. A number of examples, implemented in the REX environment, were used to illustrate the work and indicate performance in the environment.

"Programming Distributed Systems with Configuration Languages," by Justo and Paulo Cunha, described their experience of using an executable configuration language for programmed dynamic reconfiguration.

Mario Barbacci, Dennis Doubleday, Chuck Weinstock, Gardner, and Lichota described the use of triggered reconfiguration scripts in their config-

uration language, Durra. Their paper, "Building Fault Tolerant Distributed Applications with Durra," illustrates its approach with examples of using a standby with backward error recovery and n-modular redundancy and voting. The use of standbys seems to be similar to that described by Cristian except that the availability management service is to be provided by the Durra configuration management service.

DYNAMIC CONFIGURATION

This session focused on support for dynamic reconfiguration and the consistency, interference, and integrity issues involved in change management, e.g., how to preserve state information during reconfiguration. Much of the work referred to research in configuration programming on change management, which separates structural configuration changes but requires participation of components to become passive (agree to reconfiguration). This raised questions of how to determine "safe" reconfiguration states and to what extent a component has to be aware that it is being reconfigured. Discussions also took place on the difference between planned, programmed change and arbitrary, external change required for system evolution.

"Change Programming in Distributed Systems," by Georg Etzkorn also adopts the configuration programming approach, but it uses imperative change programs that have knowledge of the properties of the underlying distributed program to provide explicit reconfiguration states. This is combined with communication port blocking to try to reduce the execution delay for reconfiguration by not requiring component participation.

Node and structural integrity constraints are used by Andrew Young and Jeff Magee to constrain the configuration structures. These are used for both initial system building and to constrain change, such as may be required for repair. The constraints are specified in logic and prototyped in Prolog to provide "A Flexible Approach to Evolution of Reconfigurable Systems."

In "SURGEON: A Packager for Dynamically Reconfigurable Distributed Applications," Christine Hofmeister, Elizabeth White, and Jim Purtilo describe their system for preparing software to be capable of reconfiguration. This provides replacement and replication reconfiguration activities for modules that do not require participation during reconfiguration, and it has been implemented for POLYLITH.

Toby Bloom and Mark Day discussed "Reconfiguration in Argus," and described their concern for reconfiguration in an environment having persistent data and statically typed module interfaces, concentrating on module replacement issues.

CONFIGURATION SUPPORT

A number of different approaches to configuration and reconfiguration, particularly concentrating on the component communication aspects, were presented in this session. Much of the discussion centered on comparing the various proposals and the use of remote procedure calls (RPC).

Mark Segal described a different approach, using procedure-oriented updating rather than component reconfiguration. "Extending Dynamic Program Updating Systems to Support Distributed Systems that Communicate Via Remote Evaluation" advocates the use of asynchronous remote evaluation as a means to decouple communicating objects.

Victor Mak argued that use of a "Connection: An Inter-Component Communication Paradigm for Configurable Distributed Systems" provides more flexibility in structuring distributed systems.

The paper on "Transparent Service Reconfiguration after Node Failures," by Thomas Becker, provided another example of the use of reconfiguration to mask failures and ensure available services. The particular approach permits fault tolerance to be added after application design. Server teams use checkpointing and standby servers to provide availability.

PERFORMANCE AND PROCESS ALLOCATION

Configurable distributed systems offer the opportunity to configure, reconfigure, and allocate the application to the physical system to improve its performance. Most of the papers in this session concentrated on the allocation problem, providing load-sharing algorithms for process allocation to parallel and distributed systems.

Orly Kremien and Jeff Kramer described a scalable, adaptive algorithm for "Flexible Load Sharing in Configurable Distributed Systems." This provides distributed load-sharing managers that cooperate to disseminate load-state information upon which they make load-allocation decisions. Partitioning is used to ensure that the algorithm is scalable. A prototype has been implemented to provide an allocation service for Conic.

Phase-reconfigurable programs were investigated by Adamo, Bonneville, and Bonello in their efforts to exploit machines with low reconfiguration time. In "Virtual Machine and Software Interface for the Dynamically Reconfigurable SuperNode Multiprocessor" they describe their use of the C-NET programming environment developed for SuperNode.

In "Flexis-I: A Dynamic Configuration Model for Distributed Scheduling Systems," Kara, Jesty, and Gough described how a configuration language approach could be used to provide reconfigurable distributed schedulers.

Amnon Barak and Ben-Natan concentrated on the problem of "Dynamic Assignment of Tasks to Parallel Architectures," so that certain properties (e.g., communication overhead) are optimized. Graph embeddings and contractions are used to efficiently map task graphs (configurations of processes) into networks of processing elements (physical configurations).

MANAGEMENT

The final session of papers discussed the management of distributed systems; it dealt with topics such as heterogeneity, scale, and the relationship between trading in open systems and configuration.

Dean, Hutchison, Rodden, and Sommerville described their work on "Cooperation and Configuration Within Distributed Systems Management." This concentrates on the various forms of cooperation involved in management, using SySL (see Languages session above) as a modelling language.

"Very Large Distributed System Management: A Dependable Approach," was presented by Hodge. This work discusses the application of fault tolerance techniques to management, using objects and actions to construct state-based recovery. A prototype has been implemented using the Arjuna environment.

Herzog and Sunderhaft presented their work on a management system called DIMENSION, implemented on ANSAware. "Managing Applications in Heterogeneous Environments" argues that for managing open distributed systems, there is a need for multiple languages to support multicast and group communication, for sensor and data manipulation, for configurations and changes, for specifying management policies, and so on.

"Application Configuration in a Client-Server Distributed System" was described by Robert Cole. In particular, the problem of selecting an appropriate server by a client is addressed. A model is used to examine the decision-making process and to justify the need for a service registry, attribute depository, service and system constraints, and optimization functions.

PANEL: Issues and Future Directions in CDS

Dennis Doubleday	Juergen Nehmer
Mirek Malek	Jim Purtilo
Naftaly Minsky	

The workshop closed with a panel discussion on the main issues presented at the workshop. Despite consensus on the general models adopted for configurable distributed systems, disagreements about details still exist. This was construed to be a healthy sign of an active research area. In addition to the issues referred to at the beginning of this synopsis, others were also raised. These included issues relating to timeliness for responsive systems, data-rich systems, and formal models for reasoning about configurable distributed systems.

CONCLUSIONS

The workshop provided an excellent opportunity to present and discuss current work in this area. An indication of the success of the workshop is that the attendance rate at all the sessions never fell below about 90%! In addition, delegates filled in a questionnaire and indicated that they had greatly benefited from the workshop, and that they would very much like to have another in this research area. There is likely be a follow-on conference in about 18 months to 2 years in the United States.

PROCEEDINGS

The Proceedings of the International Workshop on Configurable Distributed Systems was published by the Institution of Electrical Engineers and can be obtained from:

IEE Publications Sales Office
Michael Faraday House
Six Hills Way, Stevenage
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Fax: +44-438-313465

Materials

Fraunhofer-Institut Für Chemische Technologie

by M. Dale Pace, Chemistry Division, Naval Research Laboratory, Washington, D.C.

KEYWORDS: research activities; FhG; thermodynamic measurements; explosion; polymer technology

INTRODUCTION

At the Fraunhofer-Institut für Chemische Technology (ICT) I presented an invited lecture on the electron paramagnetic resonance results of a new polycyclic nitramine. The ICT is in Karlsruhe, Federal Republic of Germany (FRG), and is one of 35 institutes. The collection of Fraunhofer Institutes is referred to as the Fraunhofer-Gesellschaft (FhG).

RESEARCH ACTIVITIES

The mission of the FhG is to perform developmental and applied research through government and industry contracts. The fields of research include

- microelectronics;
- information technology;
- production automation;
- sensor technology;
- materials and components;
- process engineering;
- energy technology;
- construction engineering;
- life sciences; and
- technological and economic studies, including technical information exchange.

The FhG's research activities promote the application of new technologies in German industry. The research work at ICT is principally devoted to polymer technology. The ICT's customers include polymer-producing companies, automobile manufacturers, and parts and components manufacturers. Also included are public authorities such as the Federal Ministry for Research and Development, the Federal Environmental Authority, the European Economic Community, and the German Research Society.

ICT is directed by Dr. Hiltmar Schubert. It employs about 250 research specialists and has an annual budget of about 20 million DM (DM 1.44 = $1 as of March 1992). Consequently, ICT is one of the largest institutes within the FhG. The overall areas of research at ICT are

- mechanical and thermal process engineering of polymeric materials;
- new product substances formulation and product properties evaluation; and
- environmental engineering, including waste disposal and recycling.

This triad of interests has a major subset of polymeric materials which, together with their components and raw materials, are used as energetic materials. Energetic materials research at ICT includes combustion and detonation processes and safety technology when dealing with explosives and propellants.

Energetic Materials Research

Dr. Fred Volk is the section leader of the energetic materials research. Dr. Volk's interests in energetic materials include combustion modeling, development of air-bag systems for automobiles, and environmentally safe disposal of energetic materials. He and his colleagues have developed a thermodynamic code to calculate reaction equilibria for modeling combustion. This code (ICT thermodynamic code) uses the ideal gas law and virial equation of state to calculate heats of explosions and detonation parameters such as pressure, temperature, and detonation velocity. Calculations and experimental measurements on insensitive explosives are of primary interest.

In general, thermodynamic measurements of insensitive explosives are more difficult because these explosives have slower burning rates than sensitive materials. Experimental facilities are available at ICT for measuring thermodynamics of insensitive explosives. This includes equipment for burning under high pressures, ballistic and optical test chambers to determine burning rates and spectroscopic data. A special ballistic facility can handle charges up to 0.5 kg.

Automobile Passenger-Protection Systems

The development of new passenger-protection systems for automobiles is of special interest. Since 1968, Dr. Volk has collaborated with German automobile manufacturers to develop an effective airbag system and belt-restraint system. To achieve quick response, an explosive charge is used to inflate the airbag or to restrain the seatbelt in an accident. Currently, azides such as NaN_3 are being used in these systems. Possible toxic effects of gases released by these systems is a safety concern. Safer energetic compounds for use as charge materials are being sought.

Disposal of Explosives

Disposal of explosives by burning is also related to the effects of gas release from energetic materials. In environmental research, ICT is studying the safe disposal of munitions. Since reunification, the FRG has inherited large stockpiles of explosives of which a major fraction is TNT. Because of the hazardous gases released into the atmosphere, it is not safe to dispose of these stockpiles by simply burning the materials. The ICT is searching for ways to safely dispose of these explosive stockpiles. Dr. Volk organized a conference to address this issue. The conference, Waste Management of Energetic Materials and Polymers, was held 30 June through 3 July 1992, in Karlsruhe. (Proceedings of this meeting are available: "Waste Management of Energetic Materials and Polymers—Proceedings of the 23rd International Conference of ICT, 1992," ISSN 0722-4087.

UNIQUE FACILITIES

The ICT has unique facilities for studying the effects of temperature and aging on energetic materials. A recent problem demonstrates the need for more information about explosives storage and handling. This problem involves nitrocellulose chips that are used as components of lacquers. These chips are transported separately, then mixed with lacquers at the site where the lacquers are used. Recently, a canister of nitrocellulose chips was shipped to Saudi Arabia for use as a lacquer component. Upon arrival, the canister exploded, presumably because of the high temperatures encountered in the desert. This led to an investigation of thermal aging of the nitrocellulose chips. The ICT has developed a two-fold approach to studying this problem:

1. On a laboratory scale, ovens are being used to age samples of nitrocellulose chips at constant temperatures, e.g., 35, 45, 65 °C.

2. A larger-scale operation is being conducted in bunkers outside the laboratory. Full-sized canisters filled with nitro-

cellulose chips are heated at various constant temperatures as in the laboratory. A computer-controlled system monitors the internal canister temperature changes.

Other studies are being made, such as on RDX/GAP mixtures. The laboratory is equipped with gas and high-pressure liquid chromatographs; infrared, ultraviolet, and visible spectrophotometry; and mass spectroscopy. Other equipment includes thermoanalytical devices, X-ray diffractometer, laser/doppler anemometer, high- and very-high-speed kinematography, and field facilities such as a hangar for burning studies and a test range for gas explosions up to 15,000 m^3 gas/air mixture.

Integrated Polymers-Materials Programs in the U.K.

by Joseph H. Magill, Liaison Scientist for Polymeric Materials for the Office of Naval Research European Office. Dr. Magill joined ONR Europe from the University of Pittsburgh, Pennsylvania, where he held Professorships jointly in Materials Science and Engineering and in Chemical and Petroleum Engineering.

KEYWORDS: University of Manchester; NMR; Langmuir-Blodgett; synthesis; characterization

UNIVERSITY OF MANCHESTER

The University of Manchester campus is reported to have the largest number of polymer scientists and technologists in the United Kingdom. It embodies recognized skills in polymer chemistry and physics, polymer engineering, and materials science. In a sense it comprises three universities:

- University of Manchester,
- University of Manchester Science and Technology Center, and
- Manchester Polytechnic.

All of these institutions are situated within easy walking distance of each other, and faculty and students cooperate in many areas of polymer science and technology (S&T). The complex is well equipped with conventional and modern tools of S&T so that research of high quality can be conducted. All institutions are well staffed, and the student body at the undergraduate and graduate levels is active and growing. Figure 1 shows the structural scenario of the complex.

The University complex sponsors a very active graduate seminar program. Research support is good. Funding recently has come from many sources including the United States and the United States Air Force, and active cooperative research is ongoing with Wright-Patterson AFB, Dayton, Ohio

My host in the Polymer Chemistry Department was Dr. Colin Booth. In the University Materials Science and Technology Center I was hosted by Prof. Robert J. Young. At the Materials Science Center I presented an invited lecture: "Rolltrusion: Processing-Properties-Morphology Relationships in Polymers."

Chemistry Department Nuclear Magnetic Resonance Group

The nuclear magnetic resonance (NMR) group, under the supervision of Dr. Frank Heatley, is involved in research, teaching, and service work. The facility concentrates on the characterization of polymers and colloids in aqueous[1] and nonaqueous[2] solutions and in the solid state polymer tacticity and regioregularity of polyepoxides[3] and copolymers.[4] Chain transfer (by ^{13}C NMR) in emulsion polymerizations[5] are of special interest.[6]

Langmuir-Blodgett and Thin Films

Dr. Neil B. McKeown and co-workers[7-9] are concerned with organized reactions involving assemblies of discotic mesophases and Langmuir-

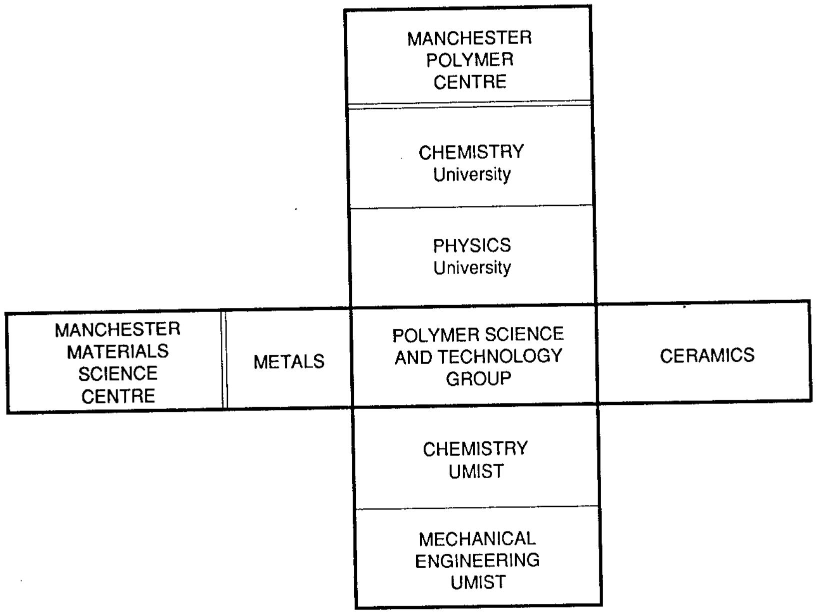


Fig. 1 - University of Manchester materials complex

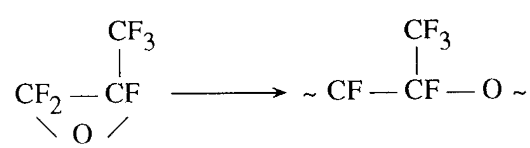
Blodgett (L-B) films of variously substituted phathalocyanines with selected substitutents. Future research is projected along similar lines that will produce thermotropic phases incorporating disc-like molecules with NLO potential and applications. This synthetic approach will provide the option to vary the metallic substituent and hence the properties.

Professor Philip Hodge and associates[10-13] have concentrated on reactive polymers and organized polymers that use L-B film methods. Research has been pursued into using polymers as chemical reagents. For example, films suitable for second harmonic generation and electro-optic modulation have been prepared and characterized. Electron-beam resists have been made from L-B films of poly(styrene/maleic amhydride) derivatives that may have potential for fabricating submicron electronic devices.

Polymer Synthesis/Characterization

Dr. Colin Booth and his co-workers[14-16] have long-standing expertise in poly(ethoxide) and other polymer chemistries. Drs. Booth and Colin Price have made definitive studies of their crystallization behavior and physical properties. Recent work has focused on the crystallinity, differential scanning calorimetry, and Raman spectroscopy where almost monodisperse monoalkyl ethers were synthesized, purified, and studied as a function of molecular weight. More recent work has concentrated on examining the effect of ethylene sequence length on the properties of polyyethylene/$LiClO_4$ polymer electrolytes, but conductivities were found to be invariably smaller here than those obtained for comparably sized polymers from polyethylene glycols with narrow MW distributions.

Other investigations with Prof. Price (sometimes as a colloborator) have been concerned with perfluoropropylene oxides of 96 percent functionality and elastomeric species. The transfer reaction:



can be controlled so that the product is claimed to be superior to the DuPont de Nemours product. Chain extension can be produced by using triazine linkages. Additionally, the polymers are versatile and can be modified to promote adhesion and bonding.

Other syntheses have been carried out with poly(ethers) to produce

$$-(-CH_2-CH_2O)_N-(\underset{|}{\overset{CH_3}{CH}}-CH_2-O)_m-$$

block copolymers. The reaction can be performed so as to minimize or suppress chain transfer. Interestingly, no transfer reaction is noted with butylene oxide and ethylene oxide. Block copolymer micellization in organic solvents have been explained.

Polymer electrolytes of the poly(ethoxides) have been shown to be more effective than Pb batteries in respect of their conductivity 10^{-4} Scm^{-2}, compared with Pb ($10^4 Scm^{-2}$) for film thicknesses of 10μm and 1000 cycles testing. For Pb specimens, the thicknesses are typically 2 cm.

Attention has also been directed toward electrochromic display materials with properties that contrast in behavior with recent reports carried out by Novacks and Grubbs at the University of California. Research on surfactants also features amongst the polymer synthesis/characterization activities in the Chemistry Department at Manchester, where controlled-release PEO-type polymers are being studied. Much synthetic effort has been put into designing polymers. Many of these and other research investigations are in progress or in the course of publication.

Manchester University Materials Science Centre

The chairman of the Manchester University Materials Science Centre (MMSC) is Prof. Sir Geoffrey Allen; the Managing Director is Prof. Colin Price. Both are in the Chemistry Department, University of Manchester. There are four directors: Dr. Harry J. Coles (Dept. of Physics), Prof. Philip Hodge (Dept. of Chemistry), Dr. Peter J.T. Tait (Dept. of Chemistry), and Prof. Robert J. Young (Manchester Materials Science Centre). The Centre also has several nonexecutive directors from industry who review the overall scientific and financial activities of the institution. In a sense, there is some similarity between the structure here and the Max Planck Institut für Polymerforschung, Mainz, Germany. Figure 2 shows the major activities in the Centre.

The Centre covers science and technology that can benefit from cross-fertilization in a multidisciplinary manner; recognized skills in polymer chemistry and physics, polymer engineering, and materials science are encouraged. A wide range of instrumentation, both traditional and novel, is on site, and instruction is provided by personnel from industry and academia.

Professor Robert Young is Head of the Materials Science Center. He provided me with an overview of the Center and its activities before my visit. It is appropriate to provide a capsule summary of his own research activities, which focus on structure and mechanical properties of polymers/composites and the effects of the chemical structure and morphology.

Faculty Research

Professor Young has recently devised a Raman spectroscopy technique[17-20] for measuring strains in high modulus fibers and strain distributions beneath the skin and core of Kevlar and other fibers. When a single fiber is deformed, the shift (decrease in) $\Delta\nu$ of the specific Raman frequency λ is appropriate to the fiber modulus. The largest shifts have been found in polyacetylene "single crystal fibers," typically those of order -20 cm^{-1}/per cent deformation have been reported for the triple-bond stretching mode. Bands with the largest $\Delta\lambda$ are generally associated with aromatic rings located in the polymer backbone. Molecular deformation and the micromechanics of fibers within composites have been investigated. This Raman technique will be used to study the mechanical behavior of many more polymeric systems that have been prepared under diverse conditions (spun and heat treated).

Research involving the use of multiphase particles to toughen glassy polymers, the effect of fillers on mechanical properties of carbon-fiber/PEEK laminates, and polymer/metal laminates used in food packaging, also feature in this investigation.

Orientational studies have just been published on biaxially deformed UHMW-PE[21] which demonstrate that both (100) and (110) planar orientation is noted. A complicated interpretation of twinning and deformation mechanisms at extensibility levels of (6×6) has been proposed.

The research of Dr. Peter Lovell[22-24] of the Polymer Science and Technology group of MMSC

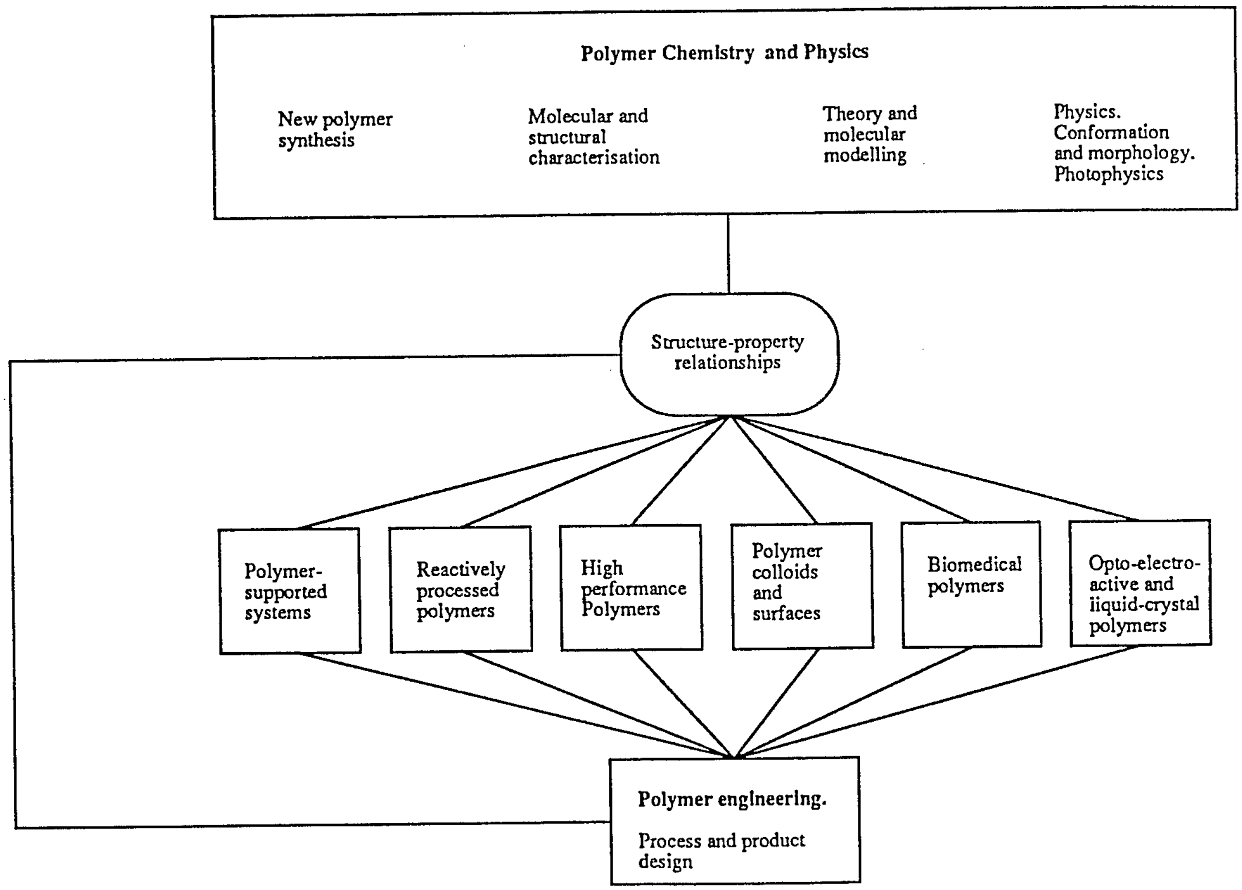


Fig. 2 - Major themes of the Centre

features the synthesis mechanism and characterization of

- random and block copolymers,
- rubber toughening with controlled size and multiphase particles of controlled morphology, and
- high-performance polymers.

In addition to fundamental issues associated with these topics, Prof. Young is interested in technological applications.[25] One of these applications, rubber toughened PMMA/(PTPMMA) with controlled morphological multilayered textures, is shown in Fig. 3. This application has been shown to induce property improvements along the lines depicted in Fig. 4.

Dr. Anthony Ryan (formerly at the Department of Chemical Engineering and Materials Science, University of Minnesota, now on the faculty of the MMSC) has ongoing research in several areas.[26-29] These include

- structure development in polyurethane foams;
- reactive injection molding of polymers and composites and modelling of properties;
- liquid crystalline networks;
- multiphase systems: characterization and control (unique polyurethane block polymers with striking mechanical and other physical properties have been produced during RIM creating spinodal decomposition during reaction); and
- multiphase polymer systems: their characterization and control (chemical and morphological). Here unique poly(urethane)

Fig. 3. Schematic diagrams of sections through the equators of the 2L, 3L, and 4L toughening particles, showing their size and internal structure: rubbery layers are dark, glassy layers are light

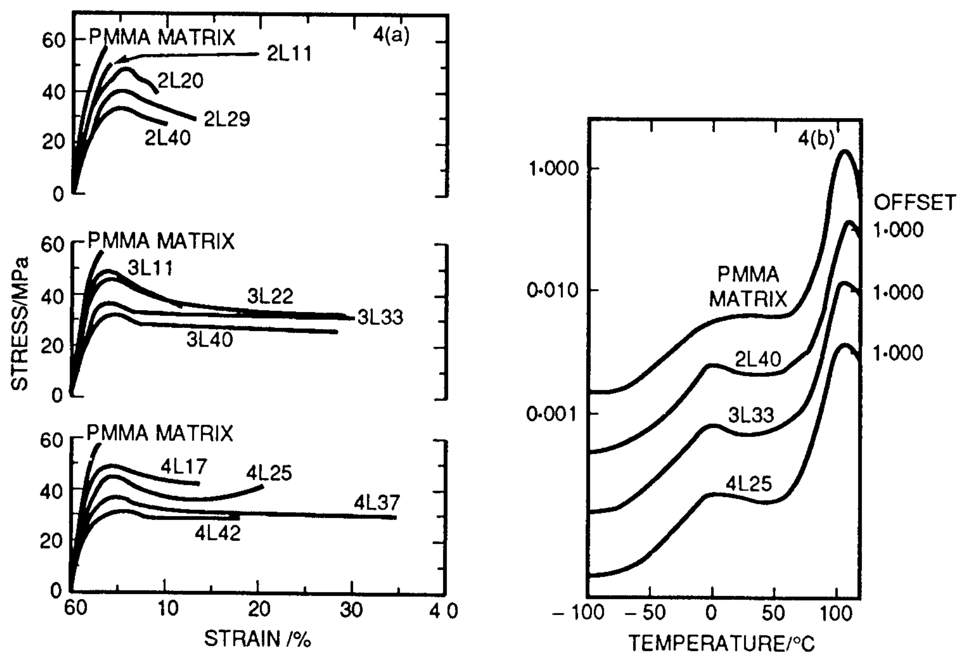


Fig. 4. (a) Stress-strain curves of the RTPMMA materials. (b) Representative DMTA spectra for the matrix PMMA and each type of RTPMMA material

and polyureas block copolymers with controlled microstructures and properties have been synthesized, characterized, and modeled.

The dynamics of microphase separation that occurs during fast polymerization reaction[27] has been followed by small-angle X-ray scattering. Thermal and mechanical properties of these copolymers have been measured and interpreted in terms of the polymer morphology determined above. Unpublished results (in press) indicate that an intriguing order-disorder transition occurs and is quantified and related to thermal and mechanical properties. The location of the transition (at about 150°C) is sensitive to MW, as theory predicts. These investigations merit consideration for technological applications.

Other investigations by Ryan and co-workers[29] have dealt with fast ring opening reactions and mechanisms in epoxy polymerizations from which polymer networks result.

Dr. Robert Stepto of the Center is a physical chemist. His research has a theoretical focus on several classical issues such as nonlinear polymerizations,[30] specifically:

- intramolecular reactions and gelation in network systems,[31] and
- network topologies and modeling of chemical reactions in reaction injection molding

Experimental and theoretical studies of polymers in solution (including phase equilibria) and their properties include general computational studies of chain statistics. Comparison of theory and experiment have resulted in agreement. For example, recent work has shown that the amount of gel-gel reaction in

(a) $RA_2 + RB_f \rightarrow$ product, and
(b) $RB_f \rightarrow$ product

random polymerizations can be evaluated. Figure 5 shows the current picture of the instantaneous probabilities.

Table 1 tabulates the gel fraction values for reactions with various functionalities f. In reaction (a), the amounts of gel-gel reaction is just about one half of those in the corresponding RA_f polymerizations. However the actual structures formed await more detailed theoretical analysis of network topologies.

CONCLUSIONS

The Manchester materials complex provides students an opportunity to diversify as well as to specialize in their studies at the graduate and undergraduate levels. The interaction that exists between faculty from diverse disciplines encourages synergism in the science and technology materials. In the writer's opinion, it may stand as a paradigm in any materials educational system that encourages learning and research in this high-technology era. Some U.S. institutions should follow its example.

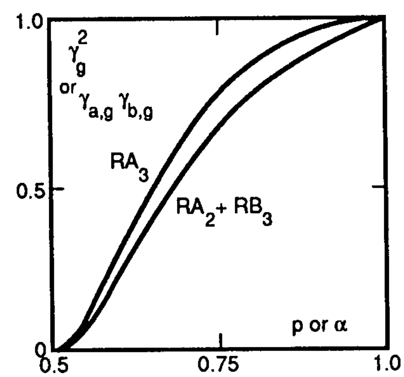


Fig. 5. Instantaneous probabilities of gel-gel reaction in RA_3 and $RA_2 + RB_3$ polymerizations vs p and α

Table 1 — Fractions of gel-gel reaction (gel-gel bonds) formed from gel point to complete reaction ($\gamma_{gg,e}$) in RA_f polymerizations and $RA_2 + RB_f$ polymerizations at $r = 1$

	$\gamma_{gg,e}$	
f	RA_f	$RA_2 + RB_f$
3	1/3	1/6
4	1/2	1/4
5	6/10	3/10
10	8/10	4/10

REFERENCES

1. F. Heatley, G.E. Yu, C. Booth, T.G. Blease, "Determination of Reactivity Ratio for the Anionic Copolymerization of Ethylene Oxide and Propylene Oxide in Bulk," *European Polymer Journal* **27**, 573 (1991).

2. F. Candau, F. Heatley, C. Prie, and R. B. Stubberfield, "An Investigation of the Structure of Micelles Formed by a Polystyrene-b-poly(ethylene/propylene) Block Copolymer in Paraffinic Solvents Using Proton and Carbon-13 Nuclear Magnetic Resonance," *European Polymer Journal* **20**, 685 (1984)

3. F. Heatley, G.E. Yu, W-B Sun, E. J. Powell, R.H. Morris, and C. Booth, Triad Sequence Assignment of the ^{13}C NMR Spectra of Copolymers of Ethylene Oxide and i,2 Butylene Oxide," *European Polymer Journal* **26**, 583 (1990).

4. F. Heatley, G-E, Yu, M.D. Draper, and C. Booth, "Analysis of the ^{13}C NMR Spectra of Poly(styrene oxide) and of Block and Statistical Copolymers of Styrene Oxide and Ethylene Oxide," *European Polymer Journal* **27**, 471 (1991).

5. P.A. Lovell, T.H. Shah, and F. Heatley, "Chain transfer to Polymer in Emulsion Polymerization of N-Butylacrylates Studies by ^{13}C NMR Spectroscopy and Gel Permeation Chromatography," *Polymer Communications* **32**, 97 (1991).

6. Frank Heatley, "Dynamics of Chains in Solution by NMR Spectroscopy," in *Comprehensive Polymer Science* (Sir Geoffrey Allen, ..Bevington, G. Price, and C. Booth, eds.)(Pergamon Press, Oxford, 1989), **1**, 377.

7. C.C. Leznoff and N.B. McKeown, "Preparation of Substituted Tetrabenzotriazoporphyrins and a Tetranaphthotriazoporphyrin: A Route to Mono Meso-substituted Phthatocyanine Analogs, *Journal of Organic Chemistry* **55**, 2186 (1990).

8. M.J. Cook, N.B. McKeown, and A.J. Thomson, Spectroscopic and X-ray Diffraction Study of Langmuir-Blodgett Films of some 1,3,8,11,14,18-hexalkyl-22,25-bis(carboxyrpopyl) Phthalocyanines," *Chemistry of Materials* **1**, 287 (1989)

9. A.S. Cherodian et al., "Mesogenic Behavior of Some 1,3,8,11,14,18,22,25-Octoalkylphthalocyanines," *Molecular Crystals and Liquid Crystals* **196**, 103 (1991).

10. P. Hodge, B.J. Hunt, J. Waterhouse, and H. Wightman, "Phase Transfer Catalysed Crosslinking of Linear Polymers," *Polymer, Communications* **24**, 70 (1983); P. Hodge, "Polymers as Chemical Reagents," in *Encyclopedia of Polymer Science and Engineering*, 2nd Ed., 12, 618 (1990).

11. P. Hodge, F. Davis, and R.H. Tredgold, "Preformed Polymers for Langmuir-Blodgett Films, *Philosophical Transactions of the Royal Society London* **A330**, 153 (1990).

12. J.R. Hill et al, "Demonstration of the Linear Electro-optic Effect in Thermopoled Polymer Film," *Journal of Applied Physics* **64**, 2749 (1988).

13. R. Jones et al., ""Electron-beam Resists from Langmuir-Blodgett Films of Poly(styrene/naleic amhydride) Derivatives," *Polymer* **28**, 1619 (1987).

14. J.R. Craven et al., "Crystallinity of Uniform Oligo(oxyethylene) Monoalkyl Ethers Studied by Raman Spectroscopy," *Journal of the Chemical Society Farad Trans.,* **87**, 3677 (1991) [see also Refs. 1,2,4].

15. J.R. Craven, Z. Hao, and C. Booth, "Crystallinity of Uniform Oligo(oxyethylene) Mono n-alkyl Ethers Studied by X-ray Diffraction and Differential Scanning Calorimetry," *Journal of the Chemical Society Farad Trans.* **87**, 1183 (1991); see also Refs. 1,2,4.

16. N.M. Nekoomanesh, C.V. Nicholas, and C. Booth, "Cyclic Oligo(oxymethylene)

Oligo(oxymethylenes) and Linear phy(oxymethylene) Oligo(oxyethylenes) Studied by Differential Scanning Calorimetry," *Makromolekulare Chemie* (Macromolecular Chemistry and Physics) **191**, 2567 (1990).

17. M. Robinson et al., "Strain Dependence of the Raman Frequencies for Different Types of Carbon Fibers," *Journal of Material Sciences, Letters* **6**, 1212 (1987).

18. J.C. Stanford, R.J. Young, and R.J. Day, "Formation and Property of Urethane-diacetylene Segmented Block Copolymers," *Polymer* **32**, 1713 (1991).

19. C. Galotis, R.J. Young, and D.N. Batchelor, "The Solid-State Polymerizations and Physical Properties of Bis(ethylurethane) of 2.4 hexadyne-1.6 diol. II Resonance Raman Spectroscopy," *Journal of Polymer Science* (Polymer Phys. Edu.) **21**, 2483 (1983).

20. R.J. Young et al., "Fiber Deformation and Residual Thermal Stresses in Carbon Fiber-reinforced PEEK," in *Comprehensive Science and Technology* **34**, 243 (1989).

21. N.S.J.A. Gerritis and R.J. Young, "Deformation Mechanism in Biaxially Oriented Polyethylene," *Journal of Polymer Science, Part B, Polymer Phys.* **29**, 825 (1991).

22. P.A. Lovell T.H. Shah, and F. Heatley, "Chain Transfer to Polymer Emulsion Polymerization of n-butyl Acrylate Studied by ^{13}C NMR Spectroscopy and GPC," *Polymer Communications* **32**, 97 (1991).

23. P.A. Lovell et al., "Mechanical Properties of Rubber-toughened Poly(methyl methacrylate)," *Plastics, Rubber and Composites Processing and Applications* **16**, 37 (1991).

24. P.A. Lovell and Richard H. Still, "Synthesis and Characterization of Poly(acrylene) Sulphides," *Makromolekulare Chemie (Macromolecular Chemistry and Physics)* **188**, 1551 (1987).

25. F.J. Guild and R.J. Young, "A Predictive Model for Particulate-filled Composite Material. Part I, Hard Particles," *Journal of Material Science* **24**, 298 (1989).

26. A.J. Ryan, "Spinodal Decomposition During Bulk Copolymerization: Reaction Injectin Molding," *Polymer* **31**, 707 (1990).

27. A.J. Ryan et al., "Dynamics of Microphase Separation During Fast Bulk Copolymerization: Some Synchrotron Experiments," *Macromolecules* **24**, 2883 (1991).

28. A.J. Ryan et al., "Thermal, Mechanical and Fracture Properties of Reaction Injection-Molded Poly(urethane-ureas)," *Polymer* **32**, 1426 (1991).

29. A.J. Ryan et al., "Networks by Fast Epoxy Polymerization," *Polymer Bulletin* **24**, 521 (1990).

30. R.F.T. Stepto, "Intramolecular Reaction and Network Formation and Properties," in *Biological and Synthetic Polymer Networks* (Elsevier Applied Science Publications, Barking, 1988), O. Cramer, ed., Ch. 10, p.153.

31. R.F.T. Stepto, "Gel-gel Reaction in RA_f and $RA_2 + RB_f$ Polymerization," *Polymer Bulletin* **24**, 53 (1990).

32. R.F.T. Stepto, "Fundamentals of the Formation, Structure, and Properties of Polymer Networks," in *Comprehensive Polymer Science, Supplement*, Sir Geoffrey Allen et al., editors, Chap. 10, p. 199 (Pergamon Press, Oxford; New York, 1992).

New Projects Dealing with Polyphosphazene Polymers

by Joseph H. Magill

Keywords: synthesis; properties; research projects; predictive technology; environmental conditions

FORT HALSTEAD, DEFENSE RESEARCH AGENCY

An opportunity to visit to Fort Halstead, Defense Research Agency (DRA), Military Division, Sevenoaks, U.K., was extended to me by Dr. Eamon Colclough and his associates. They presently are involved in new projects dealing with polyphosphazene polymers. I spent the day touring the laboratory, visiting with many of the scientists interested in polymeric materials (some had been transferred from Waltham Abbey, which is now closed).

The DRA group is presently being funded by the British Government to research polyphosphazenes. They have two grants, each for a three-year period. Work will focus on synthesis and properties, particularly aging studies, with a view to using these inorganic-type polymers for containment and/or encapsulation of explosives, etc.

RESEARCH ACTIVITIES

Fort Halstead has a full range of modern research and characterization facilities of good quality that have been built recently. Their research activities center on:

- synthesis of energetic materials and polymers;
- energetic materials (small and macromolecular properties);
- small molecule explosives;
- material binders, including polymers;
- weathering of polymers;
- predictive technology: life prediction of composite propellant motors; and
- degradation and stability of solid polymer propellants.

Because of impending cut-backs in the U.K. defense budget, it is felt that safely extending the life time of propellant charges is extremely important. Measures taken to extend the service life include

- improving the antioxidant;
- reducing storage temperature;
- lowering the cross-link density of the propellant; and
- reducing the oxygen access to the system.

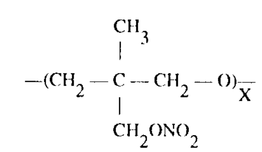
All of these ways of making improvements are in line with the above thesis. In predicting material life times, at least three critical parameters must be dealt with:

- the critical aging process and its kinetics;
- environmental conditions in service; and
- the design limits of the motor as they relate to the critical aging process(es).

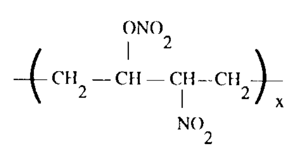
Some of these are very important issues when materials are moved or shipped from cold to warmer environments (i.e., as took place in the Gulf War).

RECENT WORK

Recent work at DRA that has demanded that their primary efforts be involved in the characterization and properties of energetic binders like poly(nitro methoxy methyl oxtane) poly(NIMMO), poly(glycidyl nitrate) poly(GLYN), and nitrated hydroxy-terminated butadiene poly(NHTPB), all of which required the development of techniques for N_2O_5 production



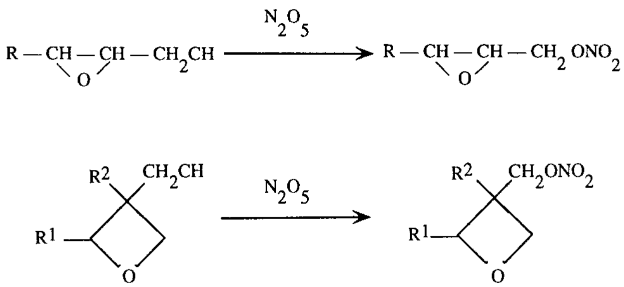
Poly (NIMMO)



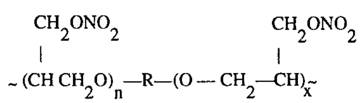
Poly (NHTPB)

Since the 1980s the exploration of the dinitrogen pentoxide as a nitration route has proved to be a very valuable and effective approach.

The synthesis of energetic monomers and hence polymers following the routes:



has lead to the continuous production of high-purity poly(IMMO). Details of this work are found in a series of papers by scientists at ICI Explosives and the DRA - Military Division, East Halstead.[1-5]



Poly (GLYN)

The two polymers are among the first of a new range of nitrated polymers developed by the RDA-Military Division and produced by ICI Explosives using N_2O_5 technology. Both poly(GLYN) and NHTPB required the development of techniques for N_2O_5 production.

New, energetic formulations that have been developed with rubber[poly(butadiene)]/binder properties for the next generation of propellants and explosives have been reported and tested and computer calculations have been made. The vulnerability of rocket propellants containing the new binder materials must await further experimental work.

Another important project is the development of reaction injection molding (RIM) for the mass production and safe handling of plastic bonded explosive charges. Considerable effort has been needed jointly by ICI Explosives and RARDE to enable RIM to be used for molding explosive compositions.

CONCLUSIONS

The new polymer research laboratories at this British Military Research Agency are impressive. New projected funding for polyphosphazene and other materials research is under way.

REFERENCES

1. A.V. Cunliffe, A. Davies, F.A. Kirby, and D.A. Tod, "Life Predictions of Composite Propellant Motors," presented at Picatinny Arsenal National Conference on Predictive Technology, Skylands Convention Center, Randolph, NJ.

2. G. Bagg, M.J. Stewart, W.B.H. Leeming, and P.F. Swinton, "Manufacture of Energetic Binders Using N_2O_5," presented at the ICI Conference in Karlsruhe 1990 and at the ADPA meeting in San Diego, April 1991.

3. D. Debenham, W.B.H. Leeming, and E.J. Marshall, "New Energetic Formulations Containing Nitratopolyethers," presented at the ICI Conference in Karlsruhe 1990 and at the ADPA meeting in San Diego, April 1990.

4. D. Debenham, W.B.H. Leeming, and E.J. Marshall, "Application of Poly(NIMMO) in Composite Sun Propellants," presented at the ICI Conference in Karlsruhe 1990 and at the ADPA meeting in San Diego, April 1990.

5. P. Flower, B. Garaty, and E.J. Marshall, "Reaction Injection Molding of Plastic Bonded Explosives" presented at the ICI Conference in Karlsruhe 1990 and at the ADPA meeting in San Diego, April 1990.

Polymer Blends and Mixtures

by Joseph H. Magill

KEYWORDS: morphology, molecular architecture, interface, interfacial phenomena, decomposition

INTRODUCTION

This article provides a basic understanding of polymer interfaces and highlights some of the issues that are encountered in the load-bearing properties of polymers and copolymers. It represents an important step in trying to link microscopic with macroscopic behavior by using new as well as established tools for materials characterization. More research is required to clarify the extent to which morphology and molecular architecture (including degree of orientation, which was ignored at the workshop described below) can influence fracture initiation under various loading conditions.

Polymer blends and mixtures have received much attention during the last decade. These systems must be understood in more fundamental terms, especially as the properties relate to surfaces and interfaces. For this reason, a one-day Workshop on "Polymer Blends and Mixtures" was held at the Society of Chemical Industry, London, on December 13, 1991. It was sponsored by the Institute of Physics. The meeting was organized and chaired by Dr. Richard A.L. Jones, Cavendish Laboratory, Cambridge.

The workshop comprised invited lectures and several scientific posters. The opening lecture, "Theoretical Problems in the Theory of Phase Separation," was given by Sir Sam Edwards, Cavendish Laboratory, Cambridge. He pointed out that many problems exist in this area and described some of these during his very rapid treatment of the subject. He began from first principles, with two polymer chains R_A and R_B

R_A (S_A)

R_B (S_B)

of the same length and Kuhn segment length, pointing out that contact interaction only is needed to treat this problem. The polymers are presumed to behave as perfect gases, and this leads to an equation that (simply and crudely) gives the shape of the polymer interface. He then went on to ask...Was the theory good enough? Does it agree with experiment? How can more appropriate equations be derived?

Two models are available from which to derive these equations:

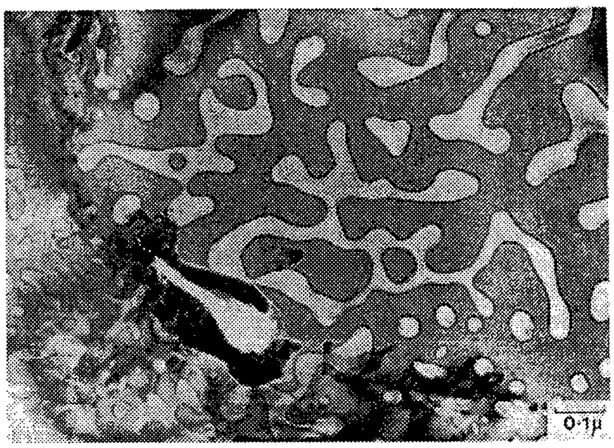
1. Flory-Huggins model[1] (F-H), which requires no "structural" detail unless one is at/near the glass transition T_g. In the F-H model

   - equation-of-state effects are neglected,
   - density fluctuations are not accounted for,
   - chain configuration is affected by composition—some chains are not necessarily Gaussian, and
   - the model overlooks concentration fluctuations (the interaction parameter χ has a composition dependence).

2. Cahn-Hilliard model (illustration from metallurgy) provided examples for phase separation for binary metallic Ag-Au(55/45 wt percent) that show a morphology similar to polymer blends (Fig. 1). Edward referenced a lecture by A.J. Forty[3] that was substantive in the phase separation approach. He emphasized that only one or two constants were required to represent polymer melts.

Equations often conceal the mathematical difficulties required to produce detailed derivations consistent with experiments. Theory is often applicable only away from the interesting experimental regions, i.e., at the glass transition temperature T_g or other places.

(a)



(b)

Fig. 1. Transmission electron micrographs illustrating the formation and growth of gold-rich islands during the chemical corrosion of a 55% silver/45% gold alloy film in 35% nitric acid solution: (a) after exposure to acid for 30 s, (b) after immersion in acid for an additional 30 s

Professor Julian Higgins,[3,4] Imperial College, described her "Experimental Studies of Polymer Mixing and Demixing." She began by stating the thermodynamic form of the Flory-Huggins lattice model for the free energy of mixing,

$$\Delta G_m/RT = n_1 \ln \phi_1 + n_2 \ln \phi_2 + \phi_1\phi_2\, \chi_{12}$$

where ϕ_1 and ϕ_2 are the volume fractions of polymers 1 and 2, and n_1 and n_2 are their respective molar numbers. χ_{12} is the interaction parameter for the polymer system. She then briefly introduced the basics of spinodal decomposition in polymer blends (Fig. 2) by using a hypothetical phase diagram for a lower critical solution temperature (LCST) mixture.

Figure 2 illustrates partial miscibility; it shows that any composition between ϕ_1 and ϕ_2 can reduce ΔG_m by the system separating into two phases of compositions ϕ_1 and ϕ_2. The solid line (the bimodal of the system) and the dotted one meet at the critical point within ϕ_1 and ϕ'; ϕ_2 and ϕ_2' phase separation proceeds by nucleation/growth processes dictated by

$$\partial^2/\partial\phi^2(\Delta G_m) > 0.$$

In the insert of Fig. 2, the system is unstable to all small fluctuations in concentration.

When a polymer blend is heated rapidly to within the unstable region of the temperature-composition diagram, spinodal decomposition takes place. Small angle neutron scattering technique is used to monitor the scattering from the two-phase region of Fig. 2. [Note that a low molecular weight system exhibits a UCST (upper critical solution temperature) curve.] This is given by:

$$S_T^{-1}\,(Q) = S^{-1}\,(0) + KQ^2,$$

where $Q = 4\pi/\lambda\,(\sin\theta/2)$ is a function of the radius of gyration and of χ_{12}. K is the slope of the scattering data expressed as:

$$K = \frac{1}{6}\left[\frac{R_A^2}{Q_A N_A} + \frac{R_B^2}{Q_B N_B}\right]$$

from which, in modified form, the radius of gyration $R_g^{\,2}/M_w$ can be obtained.

Scattering is used to obtain the temperature dependence of $\partial G_m''/\partial T$ and $\partial G_m/\partial\phi$ in the one-phase region of the spinodal. From these two types of measurements we begin to understand the molecular parameters controlling domain morphology that is obtained in phase-separating blends. In addition, tests of current theories of spinodal decomposition, particularly the Cahn-Hilliard theory, have provided a good approximation to the experimental data. However, differences also occur. Deviations from the C-H simple theory have been

noted and unaccounted for, except on the plausible basis of a contribution arising from thermal fluctuations. The polymer systems PMMA/PS-co-AN and tetamethylcarbonate/PS are noted exceptions to the C-H theory.

Polymeric interfaces were also addressed in this presentation. Neutron reflectivity studies (scattering at the critical glancing angle) have received attention in recent years for obtaining dimensional information about the interface. The shape of the interface and the magnitude of the interfacial shift is shown, and the shape of the fringes with time relates to the diffusion between species. In solution, chlorinated polyethylene and deuterated PMMA mix and then anneal at 120°C between 0 and 5200 minutes.

Figure 3 shows the change in reflectivity that occurs from having a Gaussian roughness at short times to a complex and heterogeneous polymer/polymer interface at intermediate times (thousands of minutes). Three regimes of interfacial movement are depicted, but only the shape of the interface and the magnitude of the interfacial shift can be analyzed in terms of current diffusion theories.

Interface morphology (composition and dimensions) appears to be responsible for determining mechanical and other properties of blends and copolymers in the solid state (Fig. 4). We must understand this better if we want to understand the physical characteristics of these systems.

Dr. C. Bucknall,[5] Canfield Institute of Technology, U.K., provided a more practical approach to polymer blends. His topic was "Relationship Between Structure and Mechanical Properties in Multiphase Polymers." He cited some well-known examples of toughened plastics (HIPS, ABS, PBT/PC, and epoxy and polyester resins) before dealing with the morphological structure of blends per se and their implications. He pointed out that rubber toughening was one of the key inventions in the plastics industry since property improvement became a much-sought-after goal in polymer processing. Historically, it dates back to the 1940s, before morphology-property relationships were properly understood. Basically, toughening enhances the fracture resistance of the parent polymer, at the expense of slightly reducing stiffness, yield stress, and creep resistance. For example, polymer blends that exhibit such behavior are essentially two-phase or multiphase. In general, flexibility and control in emulsion polymerization is essential to obtain enhanced mechanical properties.

Overall, the interparticle distance can be more important than the particle size per se, according to recent work. Although large particles enhance toughness better than small ones in Charpy impact testing, there are also apparent contradictions. Still, certain basic criteria or principles that prevail. For example:

- optimum toughness obtains whenever cavitation and strain-hardening occur during drawing;
- the rubber phase must be above its glass temperature;
- the rubber phase cavitates before the matrix (for closely spaced particles); and
- small particles ($< 0.1\ \mu$m) are not involved in cavitations under mechanical test conditions.

Cyclic loading under plane strain conditions in blends provides another unifying feature where shear yielding is apparent. The Paris equation[6] models this:

$$da/dn = A\,(\Delta K)^m\ ,$$

where A is a constant, da/dn is the crack propagation rate, and ΔK is the amplitude of the stress-intensity factor (where $\Delta K = K_{max} - K_{min}$). Figure 5 illustrates the results. Toughened as well as untoughened polymers tend to follow this relationship. Bucknall illustrated his lecture with many processing-property-morphology examples of polymer blends. His was an engineering approach to the topic.

Dr. Richard A.L. Jones,[7-10] Cambridge University, U.K., lectured on "Surface Segregation and Surface Driven Phase Transitions in Polymer Blends." He gave a brief historical introduction to neutron reflectometry (NR) and forward recoil spectrometry (FRS) as applied to interfaces/surfaces of polymer systems and also invoked concepts pertaining to the thermodynamics of polymer blends. With regular polymers, the strong interaction that usually obtains is a consequence of the weak entropy of mixing; segregation is stronger

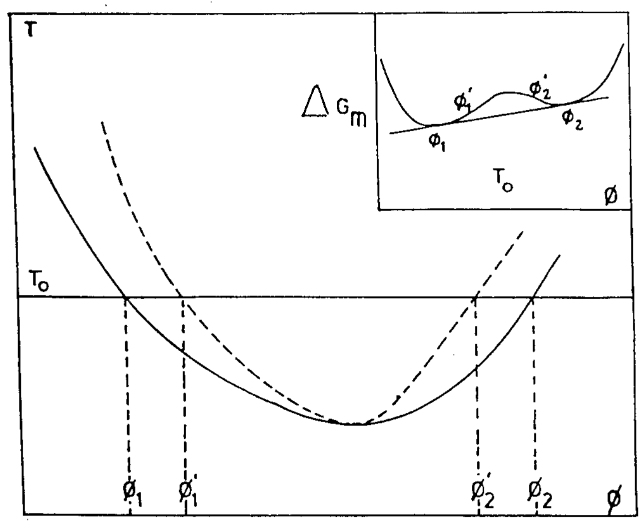


Fig. 2. Hypothetical phase diagram of a polymer mixture exhibiting an LCST

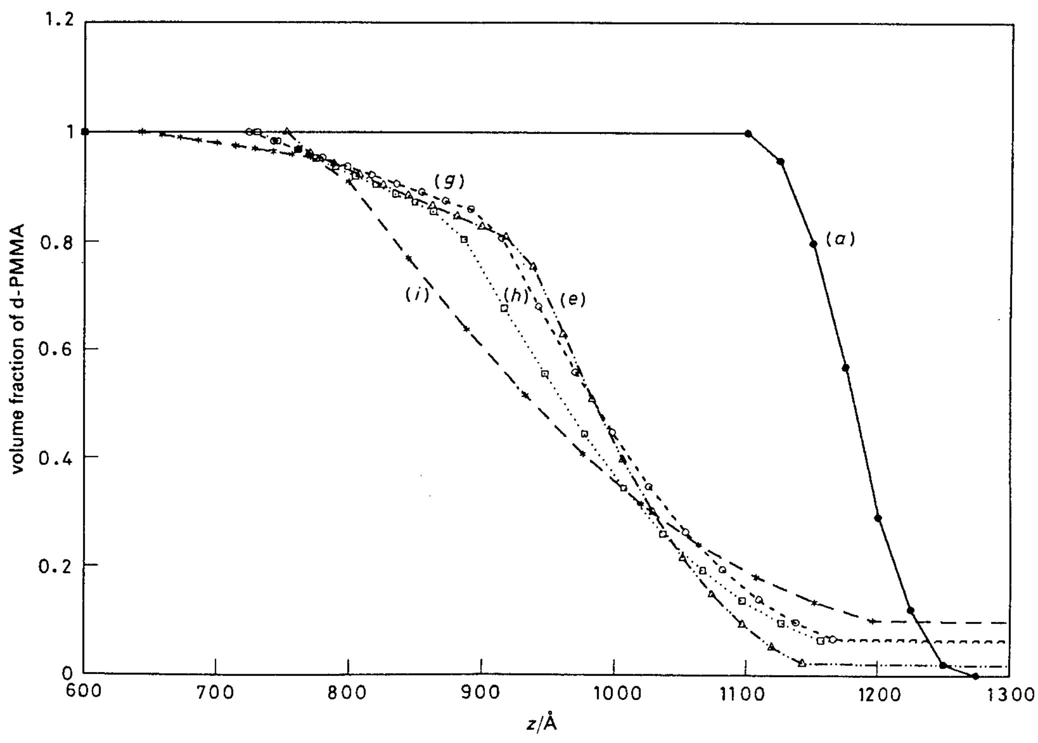


Fig. 3. Interfacial shape for the sample as made, one of the early annealings and the intermediate annealing times

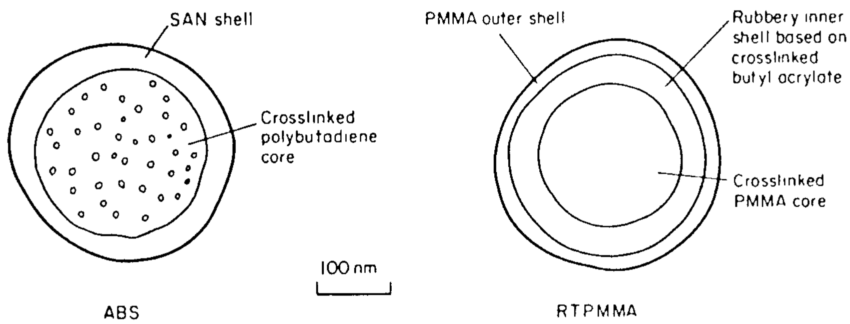


Fig. 4(a). Structure of typical particles formed by sequential emulsion polymerization. The ABS particles are made by a two-stage process. The toughened PMMA particles, which are designed to a give a transparent product, are made by a three-stage process.

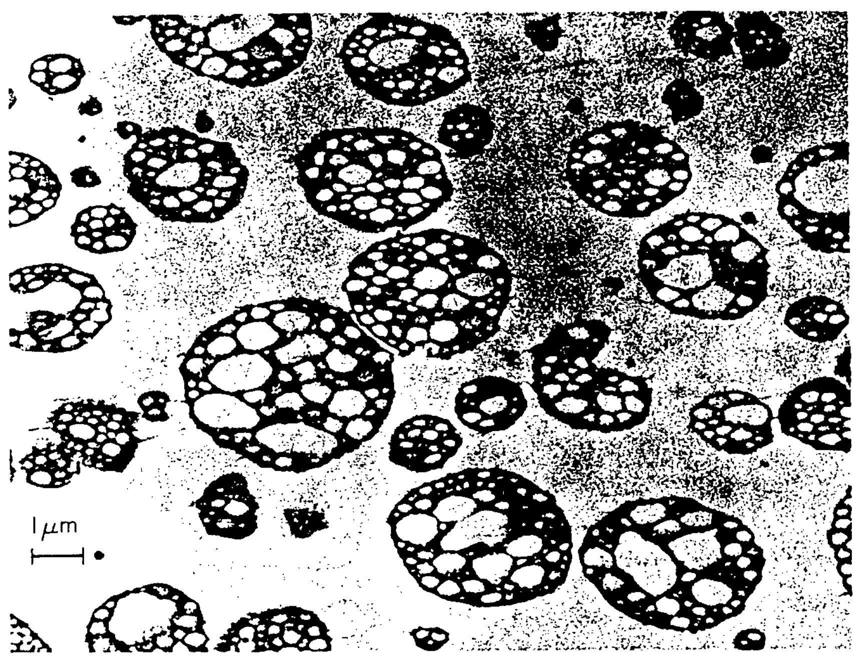


Fig. 4(b). Ultrathin section of HIPS. The PBD phase has been stained black with osmium. Note the presence of PS subinclusions within the rubber particles.

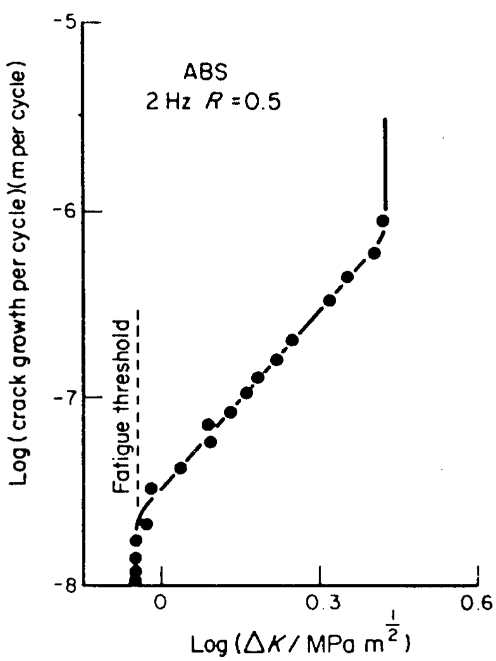


Fig. 5. A 'Paris' plot of log(da/dn) against ΔK obtained from fatigue tests on ABS. There is a threshold value of ΔK below which crack growth stops, and an upper limit on ΔK, beyond which fracture occurs as K_{1c} is reached.

when the molecular weight of the matrix is large. Neutron reflectivity is capable of probing "polymeric interfaces" to obtain the segment density profile near it. Of course, the scattering differences of H-polymer and D-polymer isotopic surface are exploited in these experiments. The D substitution may be in the main chain or in the side chains. Anyhow, the reflectivity from a multilayer structure of thickness d_i' which is perpendicular to the neutron wave vector as shown in the schematic (Fig. 6) and expressed according to the Fresnel expression as:

$$r_{n-2,n} = \frac{r_{n-2,n-1} + r_{n-1,n} \exp(2ik_{n-1}d_{n-1})}{1 + r_{n-2,n-1}\, r_{n-1}\, r_{n-1,n} \exp(2ik_{n-1}d_{n-1})}$$

for the combined reflections of the interfaces that lie between the substrate and the surface layer of the specimen.

For isotopic polymer blends, the F-H equation can be expressed as

$$G(\phi) = \frac{\phi}{N_A} \ln \phi + \frac{(1-\phi)}{N_B} \ln (1-\phi)\, \chi\phi(1-\phi)$$

where ϕ is the surface volume fraction, and N_A and N_B are the degrees of polymerization of each component that can be used to analyze the results. FES spectroscopy reveals that in D-PS/H-PS blends there is surface enrichment of D-PS relative to the bulk (see Fig. 6). The results are consistent with mean field theory, and furthermore it is found that such surface enrichment is driven by a surface energy difference that is isotopic in origin. Concentration vs depth profiles are predicted as a function of scattering intensity with measuring time and may be understood in terms of a simple Fickian diffusion mode. The characteristic equilibrium time t_{eq} may be expressed as

$$t_{eq} = \left[\frac{Z^*_{eq}}{\phi_\infty}\right]^2 \frac{1}{D}.$$

This relation is graphed in Fig. 7 for polystyrene. Conservation of mass dictates that the amount of material removed from the depleted zone must be equivalent to the surface excess amount (Fig. 8). The size of the depleted zone is of the order $(Dt)^{1/2}$ where

$$Z^x(t) = [\phi_\infty - \phi_d(t)]\,(Dt)^{1/2},$$

which gives t_{eq} as above.

CONCLUSIONS

It must be realized that the resolution of FRES is typically about 800 Å (i.e., many times the radius of gyration of a polymer molecule). Furthermore, the sampling area (for the specimen as of the order of cm^2) so that average—rather than high—surface specificity is obtained, unlike other spectroscopic techniques such as SIMS and ESCA, for example.

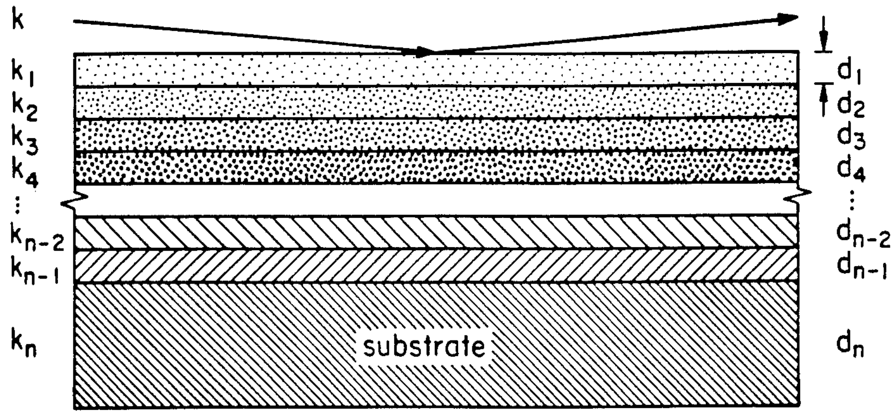


Fig. 6. Schematic multilayer structure, with layers of thickness d_1 in which the perpendicular component of neutron wave vector is k_1

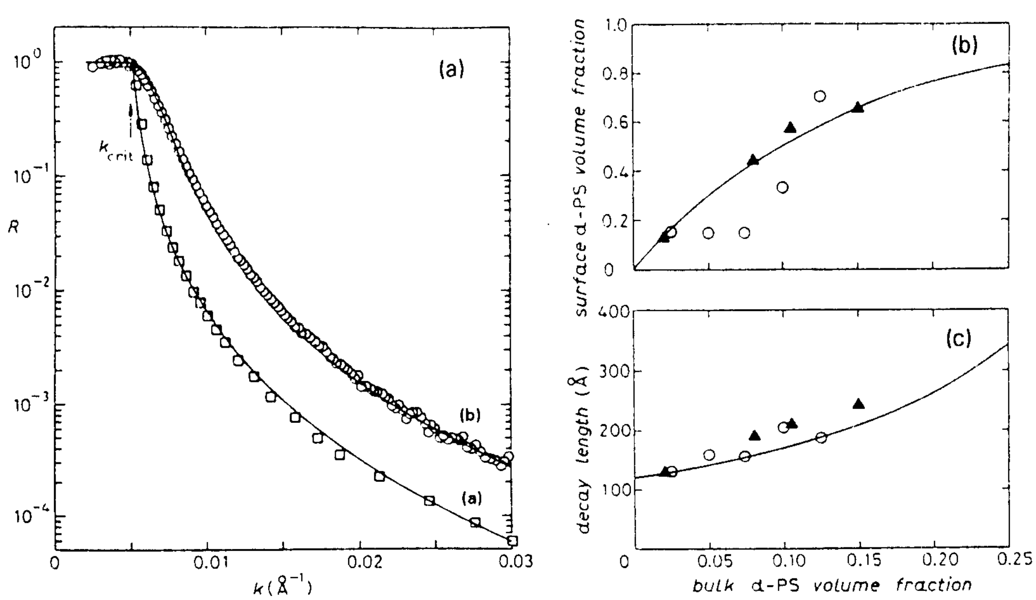


Fig. 7. (a) Neutron reflectivity R as a function of perpendicular component of neutron wave vector k for a blend of 15% d-PS with PS (a) before and (b) after annealing at 184°C for 7 days. The solid line (a) is calculated assuming a uniform 0.15 volume fraction of d-PS; the fit in (b) is the best fit to meanfield theory as described in the text.

(b),(c) Surface volume fraction of d-PS as measured by SIMS (○), as measured by NR (▲), and as predicted by theory (—). Characteristic decay length of the enriched layer as measured by SIMS (○), as measured by NR (▲), and as predicted by theory (—).

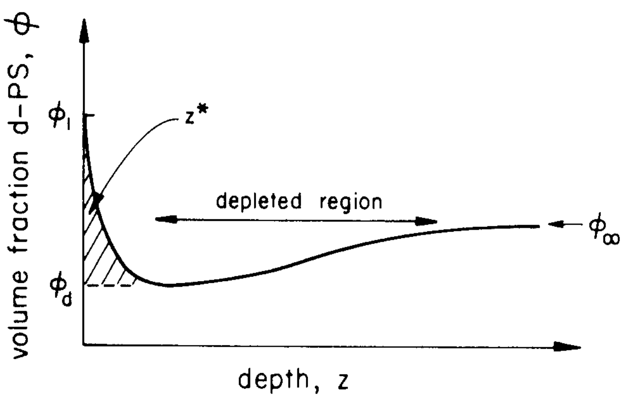


Fig. 8. Schematic sketch of a model for the build-up of a surface layer in a polymer blend

We must improve our understanding of interfaces and interfacial phenomena in blends and copolymers and correlate this with mechanical behavior in order to improve polymer properties where they are used. This is important for bridging the gap between molecular and practical properties of polymers.

REFERENCES

1. P.J. Flory, *Principles of Polymer Chemistry* (Cornell University Press, 1955)

2. A.J. Forty in *Sir Charles Frank, OBE, FRS: An Eightieth Birthday Tribute* (Adam Hilger, Bristol/New York, 1991), R.G. Chambers, J.E. Enderby, A. Keller, A.R. Lang, and J.W. Steeds, eds., pp. 164-187.

3. J.S. Higgins, H. Fruitwala, and P.E. Tomlins, "Correlation of Phase-separation Behavior in Polymer Blends with Thermodynamic Measurements in the One-phase Region," *Macromolecules* **22**, 3674 (1989).

4. M.L. Fernandez, J.S. Higgins, J. Penfold, and C. Shackleton, "Interfacial Structure for a Compatible Polymer Blend for Short and Intermediate Annealing Times," *Journal of the Chemical Society Faraday Translation* **87**, 2055 (1991).

5. C.B. Buchnell, *Toughened Plastics* (Applied Sciences, London, 1977) and "Rubber Toughened Plastics," Ch. 2, p.27, in *Comprehensive Polymer Science*, Vol. 7 (Pergamon Press, Oxford, New York, 1989), Sir Geoffrey Allen et al., eds.

6. R.J.M. Borggreve, R.J. Gaymans, T. Schnijer, and J.F. Ingen-Housz, "Brittle-tough Transition in Nylon-Rubber Blends," *Polymer* **28**, 1489 (1987).

7. R.A.L. Jones and E.J. Kramer, "Kinetics of Formation of a Surface Enriched Layer in an Isotopic Polymer Blend," *Philosophy Magazine* **62**, 129 (1990).

8. R.A.L. Jones et al., "The Form of Enriched Surface Layers in Polymer Blends," *Europhysics Letters* **12**, (1990).

9. R.A.L. Jones, L.J. Norton, K.J. Kramer, F.S. Bates, and P. Wiltzcus, "Surface-Directed Spinodal Decomposition," *Physics Review Letters* **66**, 1326 (1991).

10. R.A.L. Jones, E.J. Kramer, M.H. Rafailovich, J.Sokolov and S.A. Schwarz, "Surface Enrichment in an Isotopic Polymer Blend," *Physics Review Letters* **62**, 280 (1989).

Workshop on Regularities, Classifications, and Predictions of Advanced Materials

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Keywords: first-principles; coordinates; intermetallic properties; QSD; databases

INTRODUCTION

Quantum structure diagrams are used to query databases containing crystallographic data and chemical and physical properties of inorganic compounds. First-principles total energy electronic structure calculations are used to predict structural properties of materials. Investigators in these complimentary areas benefit from mutual exposures of ideas and techniques, and they were brought together at the Workshop on Regularities, Classifications, and Predictions of Advanced Materials. This workshop was held 13-15 April 1992 at the impressive Villa Olmo, home of the Alessandro Volta Centre of Scientific Culture in Como, Italy.

This workshop was of importance for two major reasons. First, investigators doing quantum structure diagrams (QSD) were brought together with investigators doing first-principles total energy electronic structure calculations. Second, prediction of properties of materials will certainly benefit from such mutual exposures of ideas and techniques.

The major topic of the meeting was quantum structure diagrams. These diagrams are constructed by using several theoretically and empirically derived coordinates. The use of first-principles total energy electronic structures calculations to predict the structural properties of materials was another important topic of discussion. This report discusses these topics as well as others that involve structures and regularities in materials.

QUANTUM STRUCTURE DIAGRAMS AND STRUCTURAL MAPS

The largest part of the meeting was devoted to describing and using databases that list crystallographic, chemical, and physical data of inorganic compounds. Two such databases were presented. The one most discussed was the CRYSTMET™ database, which was developed by the National Research Council of Canada. This database includes 45000 entries of binary and ternary inorganic compounds. A second database was discussed by Dr. N.N. Kiselyova of the Russian Academy of Sciences. This database includes binary, ternary, and quaternary compounds. It is being used as the basis of a computerized system for predicting the existence of new materials.

Dr. J.C. Phillips of AT&T Bell Laboratories discussed the evolution of the Hume-Rothery rules into Quantum Structure Diagrams (QSD). This process was culminated by the work of Villars, who studied 182 possible coordinate sets to find those that could reliably predict the properties of known compounds. Villars finally showed that it was possible to define a set of three coordinates for each atom to describe its contribution to the intermetallic properties. These coordinates have the property of "transferability," that is, they are uniquely specified for each atom and do not depend on the environment in which the atom is placed. The coordinates can be described as

- the number of valence electrons;
- the electronegativity (as defined by Martynov and Batsanov using experimental molecular data); and
- the "size," (as defined by using the work of Bloch, Chelikowsky, and Phillips, and Zunger and Cohen).

The development of the "size" coordinate was discussed by Dr. J.R. Chelikowsky of the Minnesota Supercomputer Institute. He showed that the size can be defined by classical turning points at the Fermi-level of the nonlocal pseudo-potentials

used in first-principles electronic structure calculations. In particular, he showed how the relationship between the *s* and *p* orbital sizes is important in separating materials into NaCl/zincblende and CsCl to form materials.

K.M. Rabe of Yale University showed how these coordinates could be used to classify known materials and predict new materials with similar properties. In particular, she showed how the many separate structures of binary and ternary materials could be classified into several "generalized structural types," depending only on the local environment of each atom. This has the effect of grouping together many compounds of similar but not quite identical structures. This means that the QSD need not be divided into many small regions, but rather can be divided into several larger regions, allowing greater statistical accuracy.

Dr. Rabe then showed how the QSD could be used to classify materials and predict the existence of new materials with interesting properties. In particular, she showed that the three classes of inorganic superconductors (Type I, "old" Type II (mostly A15s), and the high T_c cupric oxides) fall in three distinct regions of the QSD. High T_c ferroelectrics and icosehedral quasicrystals also have their own regions in the QSD. Although not all of the compounds in these regions have the desired properties, candidate compounds will be in these regions. To illustrate this, Dr. Rabe discussed the work of Villars and co-workers, who predicted new quasicrystal-forming compounds that were later discovered by experiment.

A related talk by Dr. J.L.C. Daams of Philips Research Laboratories was given later in the conference. This talk showed how most of the experimentally observed structural types fall into a limited number of atomic environment types (AET). The talk described the discovery of the AETs, including the examination of the database to determine whether the given structure was correct and the rules for determining an AET. The AET formalism makes it easy to observe the relationships between similar structure types.

Dr. D.G. Pettifor of the Imperial College of London discussed the use of phenomenological two-dimensional structure maps in the design of new quasi-binary materials. These structure maps were made by reordering the periodic table in a way that best predicted the properties of binary alloys. The compound A_xB_{1-x} can then be specified by the coordinates of A and B, defined above, and the concentration x. He then discussed the problems of $NbAl_3$ and $TiAl_3$. Although $TiAl_3$ can be stabilized in the cubic $L1_2$ structure by the addition of a third element, $NbAl_3$ cannot. However, $TiAl_3$ remains brittle, even in the cubic phase, while other materials with the $L1_2$ structure (such as Ni_3Al) are ductile. He then discussed the use of microscopic models and first-principles calculations for improving the predictions of these models.

Dr. J.R. Rodgers of the National Research Council Canada showed the validity of three principles for the formation of intermetallic compounds. These principles are the symmetry principle, which states that intermetallic compounds prefer the highest symmetry allowed by their crystal system; the simplicity principle, which says that the intermetallic compounds prefer simple crystal structures; and the chemistry principle, which says that the properties of the intermetallic compounds depend on positions of the constituents within the periodic table.

This was followed by the related talk of Dr. P. Villars. He listed the properties necessary for the formation of intermetallic compounds from given constituents, and the factors that determine the crystal structure and properties of these materials.

In the discussion following these talks, the universality of some of these principles was questioned. For example, the symmetry and simplicity principles might be a consequence of self-selection: complicated materials are not studied as often as simple materials, and they are more likely to be misidentified. However, it is true that most materials of technological interest have very simple structures.

FIRST-PRINCIPLES CALCULATIONS

First-principles total energy calculations have long been recognized as playing an important role in the development of new materials and in the study of their properties. A bibliography of all of the theoretical work in this area would be quite large, even though it has only been in the last 10 years that computers capable of handling many-atom systems have become available.

Aside from the work of Dr. Chelikowsky, the first talk in this category was given by Dr. W. Andreoni of IBM Zurich. She showed how the Car-Parrinello method, which combines the molecular dynamics of atoms with the electronic structure in one process, can be used to study the physics and chemistry of small clusters (here up to 20 atoms, although in certain cases the clusters can reach 100 atoms or more). Systems studied included Na, Be, B, C, Si, and Se clusters.

She discussed the trends in the ground-state structures of these materials as a function of cluster size. One interesting structural behavior she found was that the Si_{10} cluster is "pseudorotating." That is, the energy barriers between positions on the cluster surface are so small that the structure can reorient itself with very little change in energy. This reorientation makes the cluster look as though it is rotating, although actually the atoms have rearranged themselves.

As pointed out by Dr. Phillips, this has important consequences for our understanding of dynamics in materials. Transformations between structures with high barriers to hopping may be achieved by small rearrangements of the atoms, achieving "pseudohopping" (my word, not his).

Dr. A. Zunger of the U. S. National Renewable Energy Laboratory then discussed the problem of calculating the ground state of an intermetallic alloy by using first-principles calculations. Even if we know that a binary alloy has an FCC- or BCC-based structure and N atoms per unit cell, first-principles calculations have a difficult time searching all of the 2^N possible configurations to determine the ground state configuration. Of course 2^N is a huge number, and the time required to solve the band structure problem for one solid is proportional to N^3. First-principles calculations can easily find minimum energy configurations for simple structures such as the BCC-based CsCl structure (B2) or the FCC-based Ll_0 and Ll_2 structures. However, as the structure becomes more complicated it rapidly passes out of the reach of the current computers and algorithms. Although the principle of simplicity stated previously would indicate that the simple, easily observable structures are indeed the ones found in nature, it would be more satisfying to determine this from first principles.

The calculations of Dr. Zunger and his group do this by expanding the total energy into an Ising Hamiltonian, with the "spins" representing the occupation at each site (up for atom A, down for atom B) with couplings between nearest neighbors, second, third, and fourth neighbors. Three- and four-body interactions are also included. The coupling coefficients are found by fitting to a limited number of first-principles calculations. Of interest for this conference is the fact that the two-body interactions fall off rapidly with increasing distance, while the three-and four-body interactions are still large out to the third and fourth neighbors. However, the ranges of these interactions cannot be much larger than the third or fourth neighbors or the method would require more terms to be added to the Hamiltonian.

Once the Ising model parameters have been fixed, statistical mechanics can be used to construct a phase diagram for the system A_xB_{1-x} as a function of the concentration parameter x and the temperature T. This model considers only the configurational entropy. Thermal motion of the atoms about their equilibrium points is ignored. A lively discussion of this point took place between Dr. Zunger and Dr. Alcock, who agreed to disagree. From Dr. Zunger's report, it appears that the *change* in thermal energy as a function of x is small compared to the change in electronic structure energy and the configurational entropy, at least in the intermetallics. Dr. Zunger then presented phase diagrams constructed by his technique that showed the existence of new ordered phases that have not, as yet, been seen experimentally.

Electronic structure calculations can be used to study regularities in a sequence of systems. Dr. P.A. Schultz of GE Corporate Research and Development presented the results of a study on the B2 Group VIII—aluminides, FeAl, CoAl, and NiAl. In addition, the (not observed) B2 phase of CuAl was included in the calculation. NiAl would be a desirable structural material if it were not brittle at room temperature. It has a low density, high melting point, good strength, thermal conductivity, and oxidation resistance, and is ductile at high temperatures.

Understanding why NiAl is brittle at room temperatures is the first step on the path to finding ways to make it ductile. By studying the entire

sequence from FeAl to CuAl, Dr. Schultz was able to show that traditional explanations for the brittle nature of NiAl were not convincing. In particular, he showed that NiAl does not have a filled d-shell, and so cannot follow the Hume-Rothery rules. These rules state that BCC-based metals cannot have more than 1.5 *s* and *p* electrons/atom.

The final presentation involving fist-principles calculations was given by Dr. P.J. Kelley of Philips Research Laboratories. He studied the properties of multilayered systems of Co_nX_m, where X = Pd, Ni, Cu, or Ag. These materials have technological importance in the recording industry if the magnetization can be made perpendicular to the layers. To couple the direction of magnetization to the lattice, Dr. Kelley went beyond the usual semirelativistic approximation to include spin-orbit interactions in a non-selfconsistent way. His results for the Co-Ni system show that $CoNi_2$ (one layer of Co, followed by two layers of Ni, stacked in the $<111>$ direction) has a strong magnetization perpendicular to the Co layer. Continuing his systematic study, he found that $CoNi_5$ is nearly isotropic, while Co_2Ni has inplane magnetization. These predictions were confirmed by experiment, although the observed magnetization in $CoNi_2$ is not quite as large as that predicted by theory.

OTHER PAPERS

Other papers presented at this workshop are not directly related to the Quantum Structure Diagrams or first-principles calculations. Rather, they discuss some of the regularities that can be found in solids, and the classification of crystals.

Dr. F. Merlo of the University of Genoa talked about volume effects in binary rare-earth intermetallic compounds. He showed that the volume can be described as a simple function of composition; parameters are determined by the elemental economic volumes, the maximum volume change in the system, and an empirical parameter that depends on the atomic species and is roughly related to the electronegativity.

Dr. C.B. Alcock of the University of Notre Dame described his work with ceramic oxides. These systems are important in many technological systems. Dr. Alcock pointed out the systematics of defects in these structures. For example, although stoichiometric FeO is never observed, the defects in FeO order to form a structure similar to the ordered phase Fe_3O_4. Dr. Alcock also emphasized that the structure of these materials depends critically on the method of preparation, and only many hours of annealing will allow the stable phases to appear.

The final talk of the workshop was given by Dr. E. Path′ of the University of Geneva. He described the development and operation of the program STRUCTURE TIDY. This program converts a given structure to a standard form. Dr. Path′ showed why such a program is necessary, citing many examples of supposedly different structures that actually differed only by the choice of origin, choice of primitive vectors, and/or ordering of basis vectors.

DISCUSSION

This workshop was quite interesting to me. It seems very useful to bring together first-principles computational scientists and the people doing Quantum Structural Diagrams. Some connections between the two areas can already be seen. In particular, the fact that Dr. Zunger's Ising model expansion of the total energy works with only a limited number of terms shows that the physics of solids are mostly determined by local effects and average composition (which sets the Fermi level, for example). If we characterize the "local" effects of an atom by its "size" and electronegativity, and the average composition by the number of valence electrons, we have the three parameters described by Dr. Phillips in the first talk of this session.

Perhaps other uses for the quantum structure maps can be found. One example comes from a field I have some experience in, the search for ductile materials that can operate at high temperatures. For example, consider the brittle nature of the potentially useful material NiAl. If the notion of "brittle," or conversely, "ductile," could be quantized, regions of the QSD might be found where brittle materials are ductile. Then, elements could be searched for that could be alloyed with NiAl to move it from the brittle to ductile region. In the course of this search, other materials might be found that would have the same desirable properties as NiAl but would also be ductile at room temperature.

Molecular Biology

Cytokine Biology Conferences in France and Italy

by Dr. Jeannine A. Majde, Scientific Officer, Immunology and Medical Materials, Biological Sciences Division, Office of Naval Research

KEYWORDS: molecular linkage; interferons; endocrinology; neoplastic diseases; immune system

INTRODUCTION

Two conferences that addressed advances in the rapidly expanding field of cytokine biology took place back-to-back in November, 1991. The Annual Meeting of the International Society for Interferon Research was held in Nice, France, 3-8 November, and attracted more than 500 participants. The Third International Workshop on Cytokines was held in Stresa, Italy, 10-14 November, and drew more than 400 registrants, with little overlap. Although a strong case can be made that both meetings addressed the same medical problems and the same basic family of biological regulators, their relative independence illustrates the power of terminology and tradition in shaping the development of biology.

Interferons (IFNs) are a subgroup of cytokines (i.e., peptide hormones produced largely by the immune system and other diffuse tissues) that were named in the late fifties and defined by their antiviral and antitumor activities. They are termed simply IFN-α, IFN-β, and IFN-γ. IFNs remain a distinct specialty area driven by their potential clinical applications in viral and neoplastic diseases. This pharmacological perspective has tended to distract researchers from their broader role in the cytokine network, although the molecular linkages are now becoming clear and a few investigators are beginning to examine the physiological role of IFNs.

In contrast, the broader concept of cytokine is only a few years old. It currently embraces more than 25 distinct peptides, including the interleukins 1 through 12, tumor necrosis factors-α/β, leukemia inhibitory factor, 4 colony stimulating factors that act as growth and differentiation factors for the bone marrow, as well as the 3 interferons. Cytokines often stimulate growth of specific target cells, and other molecules sometimes classed as growth factors, such as transforming growth factor-β, may be more appropriately termed cytokines.

Complicating the concept further is the growing evidence that cytokines interface intimately with classical endocrine hormones, such as adrenocorticotropin, as well as with neuroendocrine factors such as opioids; it is also possible that they may serve as neurotransmitters. While cytokines are currently considered the domain of immunologists because stimulated immune system cells produce them in large quantities, it is probable that within the decade they will be integrated into a broadened concept of endocrinology.

Regardless of what they are called, their impact on medicine and physiology, as well as regulatory cell biology, is already profound. The summaries of the two meetings below highlight some of the practical uses of these substances in the context of their molecular biology.

1991 ANNUAL MEETING OF THE INTERNATIONAL SOCIETY FOR INTERFERON RESEARCH

As introduction, the reader should be aware that IFNs α and β are referred to as Class I IFNs and bind to one type of receptor, while IFN-γ is termed Class II or immune IFN, and binds to a distinct receptor. The two classes differ as well in basic structure, physical properties, cells of origin, and physiological function. Other than possessing antiviral activity, the classes have little in common; indeed IFN-γ is more interleukin-like than IFN-

like. In the discussion below, the use of the general term IFN will refer to Class I IFNs, while IFN-γ will be specified as such.

The meeting was organized into 8 plenary sessions, 14 workshops, a single large poster session, and a special lecture. The program and abstracts are available in the *Journal of Interferon Research*, Vol. 11, Supplement 1, November 1991.

Molecular Mechanisms of Action

The first plenary session on the Molecular Mechanisms of Action dealt in large part with the 3 defined protein classes (out of about 30 novel gene products) induced by IFNs that play a defined role in their antiviral activity: 2′-5′ adenylate (2-5A) synthetases, a 68 kDa or P1 protein kinase, and Mx proteins. Both the 2-5A synthetases (40, 46, 69, and 100 kDa) and the kinase require the presence of double-stranded RNA for activation, which is thought to be contributed by viral replicative complexes.

The dsRNA-activated synthetases produce the 2′-5′ oligoadenylates that serve as cofactors for activation of ribonuclease L, which can degrade both viral and host cell RNA but which may have a preference for viral RNA. Different synthetases seem to be involved in resistance to different viruses.

The P1 kinase, once activated by dsRNA or other polyanions, phosphorylates itself and then is capable of phosphorylating the α subunit of the protein synthesis initiation factor eIF-2. This latter phosphorylation event inactivates the factor and thus causes an inhibition of protein synthesis, including viral protein synthesis.

The mechanism by which Mx proteins inhibit viral replication is not yet known, but it is clear that different Mx proteins inhibit different viruses; influenza and vesicular stomatitis are the best characterized.

I. Kerr, ICRF Laboratories, London, U.K., in his introductory overview focused on the newly recognized viral strategies that have evolved to resist the antiviral action of IFN or its products. These include the adenovirus VAI RNAs that inhibits the P1 kinase irreversibly and the reovirus sigma3 protein that sequesters dsRNA and prevents its activation of P1.

The adenovirus E1A oncogene product inhibits transcription induced by IFN at the level of the IFN-stimulated response element. Other viral classes, including influenza, vaccinia, hepatitis B, and human immunodeficiency viruses appear to use some strategy that inhibits P1 kinase and thus allows their proteins to be synthesized.

R. Silverman, Cleveland Clinic, OH, described recent findings regarding structure of RNase L and its relationship to 2-5A and its RNA target. I. Julkunen, Rutgers University, Piscataway, NJ, described studies on Mx and its binding site for GTP. A. Kimchi, Weizmann Institute, Rehovot, Israel, discussed the growth inhibitory mechanisms of IFN, which may involve interaction with proto-oncogenes such as c-*myc*. R. Friedman, Uniformed Services University, Bethesda, MD, described the cross-linking of extracellular collagen and elastin by an IFN-induced lysyl oxidase—this action inhibits the tumorigenic phenotype and may play a role in the antitumor action of IFN.

IFN Genes

The symposium on IFN Genes described some of the complex mechanisms by which IFN genes are activated and regulated, and provided a framework for how IFNs interface with other cytokines. C. Weissmann, University of Zurich, Switzerland, described the promoters and regulatory factors involved in induction of IFN by different stimuli. J. Vilcek, New York University, NY, discussed the IFN regulatory factors IRF-1 and IRF-2, which are activated by viruses, IFN, other cytokines, and cell mitogens. IRF-1 appears two hours prior to IFN-β following dsRNA or viral induction and is a positive regulator of 2-5A synthetase; IRF-2 is a negative regulator of IFN-β. J. Hiscott, McGill University, Montreal, Canada, described the mode of action of the transcriptional activator NF-κB and its role in stimulating IFN-β transcription. H.A. Young, National Cancer Institute, Frederick, MD, described the role of DNA binding proteins in the regulation of IFN-γ. Of particular interest is the recent observation that estrogen stimulates IFN-γ production while testosterone inhibits it. In view of the central role of IFN-γ in immune regulation, this observation could account for the enhanced immunocompetence of females vs males. Mice with an IFN-γ deletion have now been bred and

may clarify its role in immunity. The transcriptional activator c-Rel binds to the same region as NF-κB on both the IFN-γ and IL-2 genes.

R.M. Roberts, University of Missouri, Columbia, MO, described two novel classes of IFN, IFN-omega and IFN-trophoblast, that apparently play a role in ruminant embryogenesis. A subsequent plenary session on IFN-induced genes revealed the complexity of gene regulation and the role of the IFN system in working out some of this complexity.

IFN Action

A workshop on IFN Action, in addition to discussing the three induced protein classes described above, covered the inhibitory effect of IFN-β on mitochondrial genes that results in suppression of ATP synthesis (J.A. Lewis, State University of New York Health Sciences, Brooklyn, NY). The inhibitory effects of human immunodeficiency virus (HIV) on IFN production and the role of IFN-α in inhibiting production of HIV by monocytes was discussed (H. Gendelman, Walter Reed Army Hospital, Washington, D.C.), as well as the transactivation of HIV by cytokines and herpes viruses (P. Pitha, Johns Hopkins University, Baltimore, MD).

IFN Therapy of Cancer

A workshop on IFN Therapy of Cancer addressed the role of T lymphocytes, NK (natural killer) cells, and antibody in the antitumor activity of IFN in a mouse model (I. Gresser, CNRS-Villejuif, France). A possible mechanism for potentiation of tumor growth by IFN in Balb/c mice was described: IFN inhibits hyaluronidase production, which enzyme increases exposure of tumor antigens and susceptibility to immune elimination (E. de Maeyer, Institut Curie, Orsay, France).

In human studies, the continued poor therapeutic index of IFN-α for various tumors was evident, but encouraging results with IFN-β, which is considerably less toxic than IFN-α, were presented (L. Kowalzick, University of Hamburg, Germany). A striking characteristic of IFN-α toxicity is the profound fatigue experienced by recipients—a possible source of the hallmark symptom of chronic fatigue syndrome.

IFN in Neoplastic Diseases

A plenary session on IFN in Neoplastic Diseases suggested that IFN-α_1 may be less toxic and less immunogenic than IFN-α_2, which has dominated earlier human trials. An inducer of IFN-α, imidazol R-837, results in the same fever and severe fatigue that has impeded the use of IFN-α itself (E. Borden, University of Wisconsin, Madison, WI). [For more details regarding the extensive clinical studies of IFNs in cancer, see the review by Baron et al., *Journal of the American Medical Association* **266**, 1375-1383 (1991).]

IFN and the Immune System

A workshop on IFN and the Immune System focused on IFN-γ. A well-known effect of IFN-γ is the stimulation of histocompatibility (MHC) antigens on cells that promote immune recognition. It also stimulates complement receptors on myeloid cells (P. Benech, Harvard University, Boston, MA). Antibody to IFN-γ inhibits allograft rejection and graft vs host disease (L. Ozmen, Hoffman-LaRoche Ltd, Basel, Switzerland), as does soluble IFN-γ receptor.

IFN-γ is also implicated in the generalized Shwartzman reaction to endotoxin, which can be blocked with IFN-γ antibody or receptor. E.N. Fish, University of Toronto, Canada, presented evidence that IFN-γ expression is defective in rheumatoid arthritis. A. Assal-Meliani, Clinique Baudelocque, Paris, France, described the immunosuppressive effects of trophoblastic IFN, which may block the maternal immune response.

H. Ankel, University La Sapienza, Rome, Italy, described the induction of IFN-α by high concentrations (5 μg/ml) of the HIV gene product gp120. P. Fitzgerald-Bocarsly, New Jersey Medical School, Newark, reported that IFN-α responsiveness of blood leukocytes of AIDS patients negatively correlated with disease progression. A novel leukocyte called the natural IFN producing (NIP) cell was found to be reduced in number and activity in AIDS patients.

R. Zawatzky, German Cancer Research Center, Heidelberg, described the role of IFN-β in autocrine regulation of virally-induced macrophage IFN activity in high and low responder mice. Low responder mice can be converted to

high responders if antibody to IFN-β is used to block this regulation. Other cytokines, such as IL-6, were also enhanced by IFN-β antibody.

IFN and Cytokines

In a workshop on IFN and Cytokines, A.C. Larner, FDA, Bethesda, MD, described the suppressive action of IL-4 on inflammatory cytokines (TNF, IL-1, IL-8) and prostaglandins, its stimulatory activity on bone marrow reactive cytokines (g-CSF, m-CSF), and its capacity to downregulate IFN-α and -γ induced gene products (ISGF3, IP10). J. Hiscott, McGill University, Montreal, Canada, reported that HIV-infected monocytes are hyperresponsive to cytokine (including IFN) induction by viruses or other cytokines, possibly because of activation of NF-κB by HIV. M.R. Capobianchi, University La Sapienza, Rome, Italy, reported that the purported acid lability of IFN-α induced by HIV is due to contamination with IFN-γ and/or TNF-α.

IFNs and the Treatment of Viral or Parasitic Diseases

Another plenary session addressed IFNs and the Treatment of Viral or Parasitic Diseases. H. Murray, Cornell Medical Center, New York, NY, reviewed the protective roles of the IFNs in infections other than viral. IFN-γ has been the most studied: it activates killing mechanisms of macrophages and is synergistic with TNF-α or antimicrobials in killing such parasites as *Leishmania*. It has shown promise as a prophylactic for sepsis in trauma and restores the microbicidal activity of defective leukocytes in chronic granulomatous disease. However, it exacerbates inflammatory disorders such as multiple sclerosis.

IFN-α is effective at blocking *Listeria*; IFN-β has been shown to be active against *Listeria*, *Toxoplasma*, and *Mycobacterium tuberculosis*. Hepatitis B virus has long been a practical target of IFN therapy, and S.M. Donohue, Royal Free Hospital, London, U.K., reported that IFN-α is effective against the newly defined hepatitis C virus as well. G.R. Foster, Imperial Cancer Research Fund, London, U.K., identified a polymerase of hepatitis B that blocks the response to IFN-α or IFN-γ.

IFNs and the Cytokine Network

The final plenary session was on IFNs and the Cytokine Network. J. Vilcek, New York University, New York, NY, reviewed common functional characteristics of IFNs and the pro-inflammatory cytokines (TNF-α, IL-1, IL-6) as well as the numerous common gene products. The same nuclear regulatory factors described above regulate both the IFNs and many cytokines. Significantly, the pro-inflammatory cytokines express antiviral activity (the original criterion for an IFN) by inducing IFN-β. In fact, IL-6 was previously termed IFN-β_2 in part because of its antiviral activity.

(**Author's note**: IFN-γ appears to express much of its antiviral activity via induction of IFN-β and might be more appropriately named something other than an IFN, as suggested above. Another source of confusion in the older literature is the fact that viruses, and/or dsRNA, induce a wide range of cytokines along with IFN, and much of the early work with crude IFN preparations actually incorporated numerous cytokine effects as well. Now that recombinant materials are available, much of this early confusion can be sorted out.)

T. Mosmann, University of Alberta, Edmonton, Canada, reviewed the cytokine profiles of helper T cells. IFN-γ is made by activated T_H1 lymphocytes along with IL-2, IL-3, TNF-α/β, MIP, gmCSF, and met-enkephalin. This cell class is important in delayed hypersensitivity reactions and macrophage activation. The cytokine IL-10 blocks IFN-γ production by both T_H1 and NK cells. IFN-γ, on the other hand, blocks T_H2 production of cytokines involved in allergic responses, such as IL-4 and IL-5, and production of IgE by B cells.

J. Banchereau, Schering-Plough, Dardilly, France, further described the role of IL-4 in allergy: IL-4 selectively stimulates the production of IgE and IgG_1 and drives the hemopoietic precursors of eosinophils and basophils as well as neutrophils. It can block the products of T_H1 cells and thus block specific inflammation. E.M. Bonnem, Schering-Plough, USA, described clinical trials of gmCSF in AIDS and cancer patients. This cytokine stimulates hemopoietic bone marrow cells and can correct aplastic anemia and promote restoration of bone marrow function following bone marrow

transplant. It appears to promote immune competence in AIDS, cancer, peritoneal dialysis, and burn patients.

SUMMARY

IFNs have tantalized clinicians for more than 30 years as potential antiviral and anticancer agents. This clinical promise has driven the commercial production of recombinant products and provided support for increasingly elegant analyses of their modes of action. However, the therapeutic index for the forms of IFN-α that have been tested remains too low to encourage its use in other than a very few types of cancer, AIDS, and life-threatening hepatitis infections. Whether IFN-β will prove clinically useful is yet to be determined.

IFN-γ, or blockers of it, may be effective in selected immune disorders, particularly transplantation. The realization that the IFNs work in concert, sometimes synergistically, with numerous other cytokines may eventually provide practical approaches to their use. The IFNs' interfaces with the neuroendocrine system, touched on only peripherally at this conference, may provide another useful target. Meanwhile, the intensive investigation they are receiving at the molecular level is providing useful insights into mechanisms of gene regulation.

THIRD INTERNATIONAL WORKSHOP ON CYTOKINES

As mentioned in the introduction, the cytokines are a diverse group of signaling peptides. Many of them promote mitosis of selected cell types, and indeed were originally classified as growth factors. They appear to mediate many of their obvious functions, including driving acute inflammation, in an autocrine or paracrine mode, i.e., localized within a tissue.

However, when stimulated more vigorously, they spill out into the circulation and play a significant role in systemic pathology through CNS actions. Interleukin-1 (IL-1) is now recognized to be the dominant endogenous pyrogen (fever-inducer). Early work with IL-1 receptor antagonist (IL-1ra, a cytokine that inhibits IL-1 by competing at the IL-1 receptor), to be described below, reveals that IL-1 is a central mediator in septic shock as well as in localized inflammation and the induction phase of specific immunity.

It also appears to play a major role in induction of slow wave sleep, social avoidance, anorexia, lethargy, and other stereotypical behavioral changes seen in infectious illness. Because IL-1 is central to so many aspects of common illnesses, its blockade by IL-1ra or other mechanisms promises to change the face of medicine.

Immune system leukocytes, when activated by infectious stimuli, are efficient producers of most cytokines and are generally considered to be their primary source. However, virtually all cells produce them in response to appropriate stimuli; recent evidence suggests that IL-1 and IL-6 may be secreted in an endocrine fashion by the adrenal. IL-1 is also implicated in the physiological regulation of body temperature and sleep. Although it has been detected within selected neurons by several investigators, its role there has not yet been determined.

Two other cytokines have been consistently implicated in the pathogenesis of both localized and systemic inflammation: tumor necrosis factor-α (TNF-α) and IL-6. Typically, following challenge with a bacterial toxin such as endotoxin, IL-1 is seen within minutes, then TNF-α, then IL-6. Interpreting the role of the individual components of this cascade is greatly complicated by the fact that they all induce each other as well as synergize with each other.

Early studies implied that TNF-α was the primary mediator of septic shock, but blockade of TNF-α has proven relatively ineffective in clinical settings; blockade of the IL-1 induced by TNF-α (by IL-1ra and other reagents) seems to be very significant. IL-6, and two other cytokines, IL-11 and leukemia inhibitor factor or LIF, along with IL-1, appear to play significant roles in driving metabolic responses to inflammation such as liver acute phase proteins, amino acid degradative enzymes, and fatty acid release.

IL-6, IL-11 and LIF illustrate another persistent observation in cytokine biology, i.e., redundancy; distinct molecules with distinct receptors driving the same response. No natural blockers for TNF-α and IL-6 other than circulating soluble receptors have been discovered to date.

Another group of cytokines, the colony stimulating factors (IL-3, g-CSF, m-CSF, gm-CSF), are

involved in the leukocytosis characteristic of the acute phase in infection. Their use in restoring bone marrow function following whole-body radiation treatment for cancer or bone marrow transplant preparation, together with the red cell regulator erythropoietin, is another commercial market under rapid development.

With this brief background, I will now summarize the highlights of the 6 special lectures, 8 symposia, 8 poster sessions (the 429 abstracts for which were published in *Cytokine*, Vol. 3, September, 1991) and 8 plenary sessions that comprised this very intensive meeting.

CYTOKINE WORKSHOP HIGHLIGHTS

A special opening lecture on the evening of November 10 was given by the Nobel Laureate R. Levi Montalcini, Rome, Italy. She described some of the potential interfaces between the factor she discovered, nerve growth factor or NGF, and cytokines at the level of both the nervous system and the immune system. NGF is widely recognized for its role in the maintenance of neurons and pituitary function. It also stimulates release of tachykinins such as substance P, which drive neurogenic inflammation and stimulate IL-1 production. IL-1, TNF-α, and TGF-β all stimulate NGF production. NGF is mildly mitogenic for lymphocytes, although the mechanism is not yet defined.

The opening session also featured the first formal cytokine lecture given by M. Sporn, National Cancer Institute, Bethesda, MD, on TGF-β. Dr. Sporn developed the concept that cytokines and growth factors couple cells to their environment and function at the level of the tissue by acting on the matrix rather than the individual cells. TGF-β is notable for its profound potency, being active within the picomolar to femtomolar range. In combination with platelet-derived growth factor it stimulates cell growth, but in combination with other growth factors (including TGF-α) it inhibits cell growth.

TGF-β_1 is a 25 kDa homodimer largely produced by platelets, bone, and spleen; two other mammalian isoforms are also defined. TGF-β has diverse actions on immune system components. It appears early after induction of T cell mitogenesis and blocks IL-2 stimulation—it is upregulated by cyclosporin A, the T cell inhibitor used in transplant patients. It suppresses NK cell cytolytic activity and is potently chemotactic for macrophages, which it stimulates to produce several growth factors plus extracellular matrix components which, in turn, sequester TGF-β.

It is involved in immunoglobulin isotype switching by B cells. Clinical applications are just beginning to be demonstrated: intravitreous TGF-β stimulates reattachment of retinas and administration at the time of surgery prevents stress-induced inhibition of wound repair. It is found in normal myocytes and disappears following ischemic damage. It attenuates experimental allergic encephalomyelitis and may mediate the initiation of oral tolerance to the inducing allergen, myelin basic protein. Antibody to TGF-β inhibits pathologic proteoglycan accumulation in immune complex glomerulonephritis.

IL-1 Receptor Antagonist

The first symposium was preceded by a lecture by R. Thompson, Synergen, Boulder, CO, who reviewed the background and current clinical trials of IL-1ra, under development by his company. IL-1ra has extensive homology to both IL-1α and IL-1β, which are structurally distinct from one another but bind to the same receptors. IL-1ra, originally found in the urine of febrile patients, is a normal downregulatory component of the proinflammatory cytokine cascade. However, it is made a few hours later than IL-1 and apparently in insufficient quantities to cope with IL-1 in systemic disease. Animal studies have shown that it must be present in 100-fold excess to effectively neutralize IL-1.

Fortuitously, IL-1ra appears to have no toxic properties itself and does not block induction of specific immunity. Its primary limitation at present is its short half-life, which makes it somewhat difficult to use in chronic inflammation. However, its use in acute inflammation is most promising: animal studies of coronary artery occlusion reveal that a 40% reduction of infarct size results from IL-1ra therapy. Mortality and most pathology in rabbits given a lethal dose of *E. coli* intravenously was greatly reduced when IL-1ra was given simultaneously.

Most impressive, however, is the Phase II trial in septic shock, a condition that normally kills

nearly 50% of its victims (more than 50,000 Americans per year) regardless of treatment. Infusion of 133 mg/hr IL-1ra reduced mortality in the first clinical trial from 44% to 16%! (**Author's note**: subsequent trials with a higher dose of IL-1ra showed a reduction of mortality to 8%, a response that can only be considered remarkable.) Other studies do not indicate that IL-1ra inhibits antibody induction or other immune functions. Early studies in rheumatoid arthritis and ulcerative colitis reveal some reduction in disease by daily subcutaneous injections.

Structure and Gene Regulation

The first symposium, Structure and Gene Regulation, was led off by a presentation on TNF-α by B. Beutler, University of Texas Dallas. TNF, like many other transient peptides (such as protooncogenes), contains the TTATTTAT octamer in its 3′ untranslated region that confers instability on mRNA containing it.

TNF is also notable for its tight regulation at the translational level and its rapid degradation once it is secreted. TNF is further downregulated extracellularly through binding to soluble receptors. Transgenic mice secrete TNF from the thymus. Neutralization of TNF activity with passive antibody from birth leads to runting and thymic dysplasia; susceptibility to several infectious agents is also enhanced in mature animals. Although TNF was named and developed for its ability to lyse tumor cells, it will probably prove more important in regulation of inflammation and/or specific immunity.

K. Matsushima, Kanazawa University, Japan, described IL-8 gene activation by IL-1, TNF and IFN-γ. IL-8, made by monocytes, fibroblasts, endothelial cells, and keratinocytes, both attracts and activates neutrophils—it is a potent mediator of acute inflammation, and its induction is inhibited by steroids.

Gene Induction and Peptide Processing

The second symposium continued along similar lines and was led off by J. Vilcek, New York University, NY, by a discussion of TNF-induced gene expression. TNF induces or activates c-*fos*, c-*jun*, NF-κB, AP-1, IRF-1, and -2, PDGF, gm-CSF, c-*myc*, c-*abl*, IL-1α, IL-1β, IL-6, IL-8, IFN-β, MCAF, IL-2 receptor, EGF receptor, ELAM-1, ICAM-1 and itself. Several genes with unidentified functions are also induced by TNF, some of which appear to be extracellular matrix components.

G. Duff, University of Sheffield, U.K., described an inhibitor of IL-1β, but not IL-1α, receptor binding in rheumatoid synovial fluid made by B cells. He also described studies of the IL-1α promoter. This appears to be responsible for variable induction of IL-1α by endotoxin in man—the number of tandem repeats in intron 6 appears to control the quantity of IL-1α produced. D. Cerretti, Immunex Corporation, Seattle, WA, described the isolation of an enzyme responsible for processing of pro-IL-1β. He proposed that the enzyme may be involved in generating the growth stimulus for IL-1β-dependent leukemias.

P. Young, Smith-Kline Beecham Pharmaceuticals, King of Prussia, PA, discussed the problem of secretion of IL-1, which lacks the signal peptide required for conventional cellular secretion. Evidence exists for passive leakage from dying cells and specific leakage following apoptosis. An ATP-dependent process may be involved in transport via the mammalian equivalent of the multiple drug resistance (MDR) genes of bacteria that are capable of transporting peptides. Transfecting monocytes with MDR-1 or MDR-3 resulted in transport of pro-IL-1, and an MDR-1 homolog is expressed in macrophages stimulated by endotoxin or gm-CSF.

Receptors and Signal Transduction

The third special lecture was by D. Wallach, Weizmann Institute, Rehovot, Israel, who described the status of TNF soluble receptor studies. Two types have been defined. They are found in ng/ml quantities in normal human plasma and are substantially elevated in inflammatory disease states and cancer. Antibody to the receptors enhances TNF action and cellular activation stimuli induce shedding via an undefined mechanism.

The third symposium was on Receptors and Signal Transduction. J. Saklatvala, Cambridge University, U.K., discussed signal transduction by

IL-1 type 1 receptor. This does not appear to function by conventional routes, although prostaglandin induction is the outcome. M. Kronke, Munich, Germany, described the more conventional signal transduction by TNF-α, which activates phosphokinase C, sphingomyelinase, and phospholipase A_2 with resultant prostaglandin production. Several proto-oncogenes and nuclear regulator factors are implicated.

R. Porat, Tufts University, Boston, MA, observed that IL-1s act as growth factors for virulent but not avirulent *E. coli* bacteria. Two bacterial receptors have been identified, neither of which are blocked by IL-1ra. Structural studies of the type II IL-1 receptor, the immediate early gene IκB, the FAS surface protein mediating apoptosis, and the IFN-γ receptor were also discussed.

The fourth special lecture was by T. Mosmann, University of Alberta, Edmonton, Canada, on the inhibitory cytokine IL-10. The essence of his talk was presented at the IFN conference and is summarized above.

Receptors and Inhibitors

Symposium IV was on Receptors and Inhibitors. A substitute for S. Gillis, Immunex Corporation, Seattle, WA, spoke on the immunosuppressive activity of soluble cytokine receptors. The p80 TNF-α receptor reduces sepsis mortality in mice and adjuvant arthritis in rats; it activity is enhanced when combined with IL-1 receptor.

Several viruses have been shown to produce cytokine receptors: Shope fibroma, myxomatosis, and vaccinia all induce secretion of TNF-α type II receptor; vaccinia also induces an IL-1 receptor-like product as well as a C4b receptor and EGF and TGF-α growth factors. An IL-10 homolog is carried by Epstein-Barr herpes virus. Such host-derived genes may serve to confuse the host's immune system, and are tentatively terms "virokines."

J-M. Dayer, University of Geneva, Switzerland, discussed the kinetics of IL-1ra, which is induced by exogenous IL-1 and peaks at the same time that the fever peaks. It is not clear whether circulating IL-1ra is derived from the same cells as the IL-1, but in vitro studies show that as monocytes differentiate into macrophages, their capacity to produce IL-1 decreases as their capacity to produce IL-1ra increases.

J.P.J. Brakenhoff, Netherlands Red Cross, Amsterdam, described a mutant form of IL-6 that competes with native IL-6 in vitro. E. Granowitz, New England Medical Center, Boston, MA, showed that IL-1ra blocks induction of proinflammatory cytokines (IL-1α, TNF-α, IL-6) by monocytes treated with IL-1β; it blocks induction by LPS of IL-1β more effectively than IL-1α. P. Ralph, Cetus Corporation, Emeryville, CA, presented evidence that IL-1ra blocks HIV replication in vitro.

J. Sipe, Boston University, Boston, MA, showed that IL-1ra inhibits the synthesis of the acute phase reactant serum amyloid A (SAA) while stimulating fibrinogen production in response to IL-1. IL-1 and IL-6 synergize with respect to SAA induction and rapidly induce IL-1ra mRNA.

Pharmacology

In Symposium V, Pharmacology, C. Dinarello, Tufts University, Boston, MA, summarized strategies for inhibiting cytokines. These include neutralizing antibodies, specific receptor antagonists, soluble receptors, anti-receptor antibodies, and natural post-receptor inhibitors such as TGF-β, IL-4 and α-MSH. A. Tagliabue, Dompe Farmaceutici, L'Aquila, Italy, presented data on an IL-1β peptide (amino acids 163-171) that displays adjuvant activity and the ability to prevent immune tolerance. However, it lacks pyrogenicity, toxicity for adrenalectomized mice, and the capacity to induce IL-6, the acute phase response or hypoglycemia. The peptide does not bind to the IL-1 receptor but is transported directly to the cell nucleus.

W. Lesslauer, F. Hoffmann-LaRoche, Ltd., Basel, Switzerland, described studies on a recombinant soluble TNF receptor that reduces mortality from LPS in mice. D. Kwiatkowshi, John Radcliffe Hospital, Oxford, U.K., described protection studies with TNF-α monoclonal antibodies in human cerebral malaria in The Gambia. J.W.M. van der Meer, University Hospital, Nijmegen, Netherlands, described protection studies with IL-1ra in murine cerebral malaria, in which antibody to IFN-γ antagonizes the protection seen.

L. Ozman, F. Hoffmann-LaRoche Ltd., Basel, Switzerland, described the protective value of soluble mouse IFN-γ receptor in acute and chronic graft-vs.-host disease

Pathophysiology

Symposium VI, Pathophysiology, was led off by S. Kunkel, University of Michigan, Ann Arbor, MI, who described the role of IL-8 and monocyte chemotactic peptide in inflammation of the lung and ischemic heart. IL-8 is induced by IL-1 and TNF-α. R. Neta, AFRRI, Bethesda, MD, presented evidence that endogenous forms of IL-1 and IL-6 are more potent than exogenous forms and IL-6 down-regulates IL-1 and TNF-α.

M. Grazia De Simoni, Istituto Mario Negri, Milan, Italy, described the control of peripheral IL-6 production resulting from intracerebral IL-1 in rats. Circulating IL-6 is blocked by IL-1ra, dexamethasone, and naloxone but is enhanced by morphine. R. Ulevitch, Scripps Research Institute, La Jolla, CA, presented evidence that CD14, induced by vitamin D, serves as a receptor for LPS in association with its binding protein.

MIF-Related Proteins

Lecture V on MIF-Related Proteins was presented by C. Sorg, University of Munster, Germany. MIF, or migration inhibitory factor, has been recognized for more than 20 years, but the family of peptides that comprise it remain only partially characterized. Dr. Sorg described a few that have been isolated, and the kinetics of their expression during inflammation. MIF components, some of which are made by T cells and act upon macrophages, may play an important role in limiting chronic inflammation.

Chemotactic Cytokines

Symposium VII was entitled Chemotactic Cytokines. Numerous peptides derived from various sources (macrophages and platelets are prominent) are capable of attracting neutrophils—IL-8 made by activated macrophages is best studied. The term "interkine" has been used for this family, but "chemokine" was proposed at the meeting as an alternative name.

S. Wolpe, Genetics Institute, Cambridge, MA, described the macrophage inflammatory proteins or MIPs. Three have been isolated: MIP-1α, MIP-1β, and MIP-2. MIP-1s are potent pyrogens that, unlike IL-1, are not affected by prostaglandin inhibitors. Although they can stimulate inflammatory infiltrates, their biological role may be the regulation of hematopoiesis through antagonism of IL-3 and IL-6.

A representative of Immunex, Seattle, WA, discussed characterization of receptors for IL-8 and related factors: Type I binds IL-8 only; Type II binds IL-8, GRO, NAP-2, and appears related to receptors for C5a and f-met-leu-phe from bacteria. M. Lackman, Heart Research Institute, Camperdown, Australia, described the potent chemotactic protein CP10, which appears to play an important role in the fibrin deposition and erythema of delayed type hypersensitivity.

New Cytokines

The final symposium addressed New Cytokines. G. Trinchieri, Wistar Institute, Philadelphia, PA, described a natural killer (NK) cell stimulatory factor, a candidate for the designation IL-12. The factor is made by B cells, induces IFN-γ, TNF-α, gm-CSF and IL-8 production by T lymphocytes and NK cells, and enhances NK cytotoxic activity. It synergizes with IL-2 for IFN-γ production and is mitogenic for T cell and NK blasts. IL-12 stimulates IFN-γ production and cytotoxicity of NK cells in AIDS patients.

M. Magazin-Marco, Sanofi Elf Bio Recherche, Labege, France, described efforts to characterize new cytokines in supernatants from stimulated peripheral blood leukocytes, focusing on chemokine activities. V. Barak, Hadassah Medical Organization, Jerusalem, Israel, described an IL-1 inhibitor from tumor cells distinct from IL-1ra; it blocks IL-1-induced fever, inflammation, glucocorticoid stimulation, and acute phase reactants but not IL-6 or TNF-α effects, and is effective at suppressing experimental arthritis in rats.

SUMMARY

It is apparent that cytokine biology, although in its infancy, already offers powerful approaches to treatment of diverse diseases involving patho-

genic inflammation, particularly sepsis. It is also apparent that this field would be much more confusing than it is without the tools of molecular biology, both to produce recombinant products and to analyze cytokine expression at the level of mRNA.

Not discussed at the Stresa meeting was the rapidly evolving field of molecular pathogenesis, in which the powerful method of polymerase chain reaction analysis is used to dissect out cytokine excesses and deficiencies in infectious diseases such as leprosy and malaria and autoimmune diseases such as systemic lupus.

Wound repair is another area where cytokines play a significant role and where manipulation may prove beneficial. Although intravenous infusion of IL-1ra appears to be an effective means of delivery of this remarkable product in sepsis, treatment of more chronic conditions and wounds will require the development of more sophisticated drug delivery systems for peptides than those that are currently available.

An undeveloped area of comparable promise to inflammation therapy and bone marrow stimulation is that of the role of cytokines from tissues other than the immune system in homeostasis—for instance, the IL-1s produced by adrenal chromaffin cells, neurons, the endothelium and skin keratinocytes.

As mentioned in the introduction to this article, the cytokines appear to play an integral role in the classical endocrine system (indeed, IL-1 may prove to be the primary trigger of the stress response) and possibly the nervous system. From our current vantage, the potential applications of cytokine biology in both civilian and military medicine are virtually limitless.

Physics

Central Institute for Solid State Physics and Materials Research (Dresden)

by C.T. Owens, who was Head of the National Science Foundation's Europe Office from mid-1990 to mid-1992. He is currently working on detail to the Department of State as Senior Advisor in the Oceans and International Environmental and Scientific Affairs Bureau, and in the Politico-Military Affairs Bureau.

KEYWORDS: Max Planck Institutes; research; electron beam microscopy; laser technology; industrial connections

[Note: This visit took place in July 1992. It reflects the viewpoints of the individuals interviewed. The final paragraph, however, contains comments by the author.]

The Central Institute for Solid State Physics and Materials Research is directed by Professor Dr. Wolfgang Pompe; he is assisted by Dr. Klaus Muller. The Central Institute is presently composed of eight research institutes that specialize in various aspects of materials and solid state physics research. As a result of the recently concluded evaluation by the federal Science Council, however, administration of the various units will changing. Four institutes will be consolidated to form the Institute of Solid State Research and Materials Science and will employ about 300 people. An additional 300 people will be employed in two Fraunhofer Society Institutes, a Fraunhofer Society research group attached to the Fraunhofer Institute in Bremen (powder metallurgy and laminated materials) and a Max Planck Society (MPS) Institute (mechanical and heterogeneous media, paired with the MPS Institute in Stuttgart). The total

number of people employed in the new institutional framework will be down from 913 at the end of March, 1990. These reduction and others taking place in eastern Germany are likely to be explosive.

The institute has been pursuing a number of lines of research, including quantum mechanical and chemical analyses of high-temperature superconductors, high conductive polymers, multilayer structures in the nanometer range, superlattices, CVD and PVD multilayering, and laser technology surface treatment techniques. In ceramics, work is focused on silicon nitrides, silicon carbides, and aluminum functional ceramics. Applied research has included high-speed quenching work on both amorphous metals and ceramics, and various aspects of powder metallurgy and fiber technology.

The institute currently has excellent equipment and facilities, including those for the production and forming of ceramic/metal powders and fine ceramics; lathes, rolling mill, and other equipment for processing materials; and sputtering and vapor deposition. There are facilities for electron beam microscopy (including in-situ studies) and for ion beam microscopy. A number of lasers are on hand for application of coatings, for the treatment of metals and other materials, and for the deposition of thin films. A Rofin 6 kW CO_2 laser is used for the coatings, and a 400 kW laser is used for cutting (with a 1 kW model to be delivered). A 2-joule excimer laser pulse is used for the deposition of thin films and superlattice work.

The institute had many industrial connections in the DDR, but industry has gone down a great deal since the unification of Germany. Programs of the federal Ministry of Research and Technology have helped the institute to obtain contacts and contracts in the western part of Germany and elsewhere. The institute still has good contacts with researchers in the former U.S.S.R., where basic research in fields related to the institute's work is very good.

NSF/EUROPE Comment: This institute is located in a large building with facilities for both small pilot plants and for laboratories that use a large variety of techniques for materials development, production, testing and modification. Its successor organizations testify not only to the range of its research—from the fundamental to the industry-applied—but to the quality of that work. Although 100 of the institutes of the former Academy of Sciences of the DDR were evaluated by the Wissenshaftsrat, only 17 Fraunhofer Society institutes (and fewer Max Planck institutes) and 20 "blue list" institutes are being set up in the east.

Institute for Solid State Physics and Electron Microscopy (Halle)

by C.T. Owens

KEYWORDS: Fraunhofer Society; cooperative research; microlectronics; microscopy; materials

[Note: This article was written in July 1992. It reflects the viewpoints of the individuals interviewed. The final paragraph, however, contains comments by the author.]

The Institute for Solid State Physics and Electron Microscopy is directed by a group of senior researchers, including Prof. Dr. V. Schmidt, Prof. Dr. M. Khron, and Prof. Dr. U. Messerschmidt. Within the countries of socialist Eastern Europe, this institute was an international center for analyses, specializing in solid-state physics and the application of electron microscopy techniques. It was an institute of the Academy of Sciences of the former German Democratic Republic (DDR). The recent evaluation of the institute by the federal Science Council (Wissenshafstrat) was very favorable in terms of the quality of work being done here. The institute has 148 researchers, of which 61 are researchers.

Next year, most of the work of the institute will be carried on in a new institute of the Max Planck Society. The new institute will have 26 researchers, 60 technical staff, and 10 doctoral students. Only 15 of the researchers will be permanent employees, and the rest will be on contract. The Fraunhofer Society will set up another group that will be connected to the Materials and Mechanics Institute in Frieburg. An additional 15-20 researchers from this institute will be in the Fraunhofer group, which will be expected to achieve the Fraunhofer standard of 80% funding from contracts within three years. The remainder of the funding will come from the federal and länder governments. An additional 5 to 10 researchers will be working at a Regional Microdiagnostics Center, which is currently a unit of this institute.

Under the DDR this institute had unusually good connections with the West. In the last few years, about 50% of the researchers had a chance to travel to scientific meetings in the west. It was also possible for the institute to receive—as it did—visitors and researchers from western countries. During the last 5 years, 6 to 10 people went in each direction for longer-term stays, and 15-20 travelled to meetings in each direction. This was possible largely because of the efforts of the institute's founding director, Prof. Dr. Heinz Boethge. He told the DDR authorities that if they wanted to have the capability in the DDR to do the things that this laboratory could do, such exchanges would have to be permitted.

The institute's work was important in the development and performance of the DDR microelectronics industry. Work of the institute includes areas such as

- measuring the energy levels of defects in semiconductors;
- scanning deep-level transient spectroscopy;
- analyzing in situ thermal and mechanical stress of materials by using a 1 MeV electron microscope to accommodate large samples;
- studying surface effects and properties at the atomic level by using a 400 kV high-resolution electron microscope;
- studying defects in surface films via electron emittance microscope (ultraviolet light causes emission of electrons from the surface; these are collected and focused on the lenses; lateral resolution is in the nanometer range); and
- analyzing monatomic layers, including electronic and energy state changes.

The institute is organized today into several groups that conduct research on

- low plasticity materials,
- interfaces and microstructures in ceramic systems,
- amorphous thin films,
- structural formation of ultrathin 2-dimensional epitaxial metal films,
- electron microscopic structural analysis for materials research in the nanometer range, and
- formation and interaction of extended defects and point defects in semiconductors.

In addition to the research groups, there is an instrument laboratory that has facilities for ultra-high vacuum analyses, electron microscopy preparation techniques, high-voltage electron microscopy, high-resolution electron microscopy, analytical electron microscopy, and scanning electron microscopy.

Another laboratory is dedicated to cooperative research, testing, and analyses with organizations within the State of Saxon-Anhalt, and an International Center for Electron Microscopy. The latter, although in existence since 1975 for cooperation with Eastern Europe, will from 1992 be dedicated to building bridges between East and West.

NSF/EUROPE Comment: The Institute for Solid State Physics and Electron Microscopy was favored with a strong and effective leader in Prof. Boethge, and with being in the right field at the right time. The result is that this is one of the least isolated and most up-to-date laboratories in the East. They have been innovative in the use and modification of the equipment available to them—as in the use of the 1 MeV JEOL electron microscope fitted with custom-made stages for in situ deformation studies. The institute apparently had no trouble obtaining the high-quality JEOL equipment.

Policy

Changes in Polish Science Policy: The Copernicus Center Faces a Variety of Uncertainties

by C.T. Owens, who was head of the National Science Foundation's Europe Office from mid-1990 to mid-1992. He is currently working on detail to the Department of State as Senior Advisor in the Oceans and International Environmental and Scientific Affairs Bureau, and in the Politico-Military Affairs Bureau.

KEYWORDS: Public Law-480; physical plant; Ph.D. programs; astronomy; physics

[Note: This facility was visited in October 1991. The article reflects the viewpoints of the individuals visited. The final paragraph, however, contains comments by the author.]

THE COPERNICUS CENTER

The Copernicus Center was dedicated in 1978 as a joint United States/Poland project; it was funded with $1.5 million from the allocation of Public Law-480 currency to the National Science Foundation. In 1978, the expectation was that the Center would be a building full of astronomers and physicists. However, in the early 1980s, many Center researchers emigrated (although some have now returned to Poland). Currently, part of the building is still occupied by the Space Research Institute of the Polish Academy of Sciences. When that institute moves to new quarters soon, the space will probably be rented out.

The Center has 11 professors, 15 postdoctoral researchers, and about 10 graduate students on its staff. Over time, the Center should evolve into a graduate school, including perhaps applied mathematics among the fields that it would teach. The Center granted 17 Ph.D.s last year, including 12 to Center students and 5 to outside students.

The Center has a good library, including international periodicals, and a modest computer center. New computer equipment is being installed and sits beside the highly outdated hardware that it is replacing. There is a meeting room for perhaps 250 people where a cycle of weekly lectures on astronomy is presented to the public.

The main work of the Copernicus Center is still basic research. The Center has maintained close ties with international science, primarily in the United States and has engaged in cooperative research programs with American researchers. Some of these projects have been supported by the National Science Foundation. In fact, it was expected that more Americans would come to the Center to do research. Hopefully, this will become more the case in the future. Some Poles who have emigrated are likely to return to Poland now. However, even those who are highly motivated to return may be discouraged if funding for science in Poland is not increased. Science and scientists are in a relatively bad position within the Polish economy. The question for the Center is as it is for other Polish research institutes—how to survive the two-to-five years that it will take for the economy to catch up?

NSF/EUROPE Comment: The Copernicus Center physical plant—like many of its peers in the formerly-Socialist Eastern Europe—has been allowed to deteriorate. The intellectual endowment, on the other hand, seems in very good shape. The leadership of the Center has a clear view of the problems to be faced in the near-term. Despite the obvious difficulties, research proceeds in touch with the larger scientific community and the latest research results. Repairs to the physical plant are under way, a gesture for the future as well as attention to present necessity.

Evaluations by the Länder Government: A Hopeful Revival of Historic Ties for Griefswald University

by C.T. Owens

Keywords: Mecklenburg-Vorpommern; molecular genetics; medical faculty; law faculty; geology

[Note: This article was written in March 1992. It reflects the viewpoints of the individuals interviewed. The final paragraphs, however, contain comments by the author.]

INTRODUCTION

Ernst-Moritz-Arndt University Griefswald was founded in 1456. It has long been an important center for education and training of students from Scandinavia as well as from Germany, Poland, and the Baltic states. The university today is awaiting the changes that will come following evaluations being carried out by the länder government of Mecklenburg-Vorpommern. The physical plant needs work, and the student population is declining. Nonetheless, new equipment is coming into research laboratories, and science faculty members are designing research programs to fit the new circumstances—as well as continuing interesting existing work.

MEETING WITH THE VICE-RECTOR

The Vice-Rector of Ernst-Moritz-Arndt University Greifswald is Professor Dr. Falko H. Herrmann. The largest faculty today is the Medical Faculty; it contains 2,800 people, a hospital, and a clinical research program. One measure of the strength of this faculty was that the field of molecular genetics was pursued successfully here despite great opposition under the former German Democratic Republic (GDR). The opposition came from the politically more important health research complex at Berlin-Buch, which saw to it that resources were funneled away from Greifswald. The medical faculty today is complete and competitive with analogs in the western part of Germany. Specialties include molecular biology, molecular genetics, endocrinology, and dentistry.

The Law Faculty is the newest, having been re-founded in July, 1990. There will be 12 professors in the Law Faculty, which now has 180 students and more applicants than places for students. The Philosophy Faculty is being completely restructured.

The University has a complete program in science. The Faculty of Mathematics and Natural Sciences has Departments of Biology, Chemistry, Geography, Geology, Mathematics/Information Science, Pharmacy, and Physics.

The university staff is currently being evaluated to determine who should remain and who should leave. Setting up the final structure for the university is awaiting the results of this evaluation—which has been too long delayed. The leadership (rectorate and deans) at this university are all people who were suppressed under the old regime. People not favored in the old regime cooperated to share research materials and equipment. People who were able to "get out" for a meeting would bring home restriction enzymes, reagents, or other materials that could not be obtained in the GDR. These materials would be sent to colleagues in other organizations who thus carried on their work despite official disfavor. The sorting-out here took place before the unification of Germany. The länder government has been slow to complete the evaluation that will allow the university to set up permanent faculty positions.

DEPARTMENT OF CHEMISTRY

The Department of Chemistry is headed by Professor Dr. Gerhard Herzog. The Department has five institutes that provide instruction for the Diplome degree: Inorganic Chemistry, Organic Chemistry, Physical Chemistry, Technical Chemistry, and Teacher Training in Chemistry. Currently, 16 faculty members are in the Department, but

this number will be reduced to 12. Out of 343 students, only 12 are majoring in Chemistry this year, although 30 is the more usual number. The long-term steady-state condition should be 60 Diplome students majoring in Chemistry and 40 to 50 in teacher training (vice 25 today). Under the DDR, the number of students who could attend the university was controlled. That is not the case today, and it will help eventually to increase the student population. Another thing that will help is that a degree can be obtained in five years at Greifswald, but it takes six or six-and-a-half years in western Germany. (Students there often cannot get required courses when they want them.) One problem that will remain for a while is that housing for students is not so good.

There are 20 to 25 doctoral students doing research in the Department. Some research is supported by the Ministry of Research and Technology (BMFT) and the Deutsche Forschungsgemeinshaft (DFG). The Chemical Industry Forum also supports research. Before 1989, under the DDR, there were good connections to industry and research was done for industry, but this has dried up. The university must look for new support and for a new system to place its students. With time, this will be possible.

Inorganic Chemistry Institute

The Inorganic Chemistry Institute has three professors. It has several ongoing research projects in coordination chemistry, homogeneous catalysis of organics, organometallic chemistry, organic phosphorus, and organic silicon. Some interesting work has been done on phosphene chiral chelate ligands for use in separation of catalyst compounds, on the synthesis of low-coordinated silicon compounds, and on the development of a lithium iodide battery with polymer electrolyte and polyiodide cathode materials.

Organic Chemistry Institute

The Organic Chemistry Institute has three professors and two docents (similar to an associate professor), but it will soon have only one professor and two docents. There are five students majoring in organic chemistry, down from a usual 15 or 20, and four doctoral students. Although the institute had done a great deal of applied research in the past, little is under way today. Some current work includes hydrofluoride gasoline synthesis and heterocyclic chemistry (looking for pharmacological effects).

Physical Chemistry Institute

The Physical Chemistry Institute has research under way in the kinetics of reactions, analysis of dioxin-like compounds, solid-state chemistry (including solid electrolyte gas sensors), luminescence of inorganic substances, and rare-earth-doped substances.

GEOLOGICAL SCIENCES DEPARTMENT

The Geological Sciences Department is headed by Professor Dr. Rolf Langbein. Seven professors in this Department provide instruction in:

- Regional/Structural Geology
- Geophysics
  Geo-informatics
- Historical Geology
- Geochemistry
- Economic Geology
- Petrology
- Paleontology.

There are also usually one or two docents and one or two assistants (who are waiting for the Dr. Habilitatus degree), and 23 instructors. Approximately 150 students in the Department are now working on the five-year Diplome degree. There are also 10 to 20 postgraduate students, some of whom are engaged in field research. Students from this area are going to the west, and the university is in transition; only three students entered the geology program this year.

This university was one of only two places to study Geology in the DDR. Now there are new faculties of Geology in Jena and in Halle, and this Department will specialize in geology of the Baltic region. Some interesting research under way in economic geology involves particulate matter in the Elbe and Oder rivers. Clay particles are being collected and analyzed for, among other things, the presence of heavy metals and biological materials. Studies of sediments in the Greifswald area are

using cores of one to three meters, again checking for the presence of heavy metals. These projects should give some idea of where various contaminants may be present and of transport and migration mechanisms. There are four people working on ocean geology; another four are working on coastal sedimentation, artificial sedimentation, sediment balance, and storm effects.

The Department has a wide variety of equipment that is used in research and for training students. The scanning electron microscope (SEM), with Verex microprobe, is used in the detection of heavy metals such as Pb, Hg, Ba, and phosphates in very small grains of kaolin. The Verex 770 X-ray fluorescence machine uses the same computer as the probe on the SEM. There is a thermal analytical laboratory that contains a variety of equipment, including some for dilatometry measurements at 1,500°C. There are two transmission electron microscopes (one with a microprobe by Tesla), an X-ray spectrometer, and several pieces of equipment (by Seifert and Link) for the analysis of water samples.

DEPARTMENT OF PHYSICS

The Department's Chair for Plasma Physics is held by Professor Dr. Sigismund Pfau. Dr. Christian Wilke is also in the Plasma group, and Dr.-Student KlausDieter Weltmen is doing postgraduate research in Applied Physics. The Department has 180 students and 35 researchers, including 6 or 7 doctoral students. Instruction is given in theoretical physics, theoretical plasma physics, experimental plasma physics, and teacher training in physics.

Research in plasma physics includes experimental work on plasma wall interactions in the preparation of thin layers of titanium compounds including titanium oxide, titanium nitride, and titanium carbide. Experimental apparatus has been devised to measure the plasma's physical parameters and those of the surface layer material, and to study the dynamics of linear and nonlinear behavior in cold plasmas.

Theoretical Physics

In Theoretical Physics, two groups are working on non-ideal plasmas and various nonlinear problems, including nonlinear dynamics and chaotic dynamics. Knowledge gained is being applied to motions in plasmas. Also of interest are problems of plasmas where the application of quantum statistics is necessary—where attraction exceeds kinetic energy.

Applied Physics

Applied Physics research includes work on the conversion of speech to digital signals and back. The group is also working on the development of equipment for experimentation with plasmas where the plasma being investigated is not disturbed by the measurement of its properties—a kind of noninvasive diagnostic tool. This apparatus has been used to study the nonlinear behavior of neon glow discharge.

NSF/EUROPE Comment: Greifswald University, like its Rostock sister, is being hit hard by the fact that students now have many choices for a university education. Its location in the far northeast corner of Germany has been a handicap of sorts that the present leadership hopes to turn into an advantage for the future. Historical ties with Scandinavia and with other countries in the Baltic area will be revived and perhaps turned into growth in the student body.

The science faculty presents a series of contrasts: In Chemistry, highly sophisticated equipment is turning up in niches of a physical plant that has been allowed to deteriorate badly. The Geology Department has extensive laboratory facilities and a large collection of geological specimens but only three new students to work on or with them. The Physics Department has a very active research program, on a few topics, jammed into very little space. Throughout are people concerned about the future and about how to educate students, and to conduct research, of high quality.

They have done some interesting things with few resources in Greifswald, and additional resources are on the way. The key question is whether those who remain after all evaluations are completed will be able to develop the centers of excellence that will be needed to secure a future to rival the history of this university.

Science in Slovenia

by F.E. Russell, Research Professor of Pharmacology and Toxicology in the Health Sciences, College of Pharmacy, University of Arizona, Tucson.

KEYWORDS: University of Ljubljana; education; research; redirection; cooperative studies

In the ex-communist areas of Eastern and Central Europe, few countries (and none for its size) are as advanced in technology-oriented research as Slovenia—a country the size of West Virginia. Slovenia boasts two major universities, more than 40 independent Institutes, 68 Faculties and Schools, more than 9000 researchers, 30 University Clinics, and more than 150 research and development units, mainly in industry. Approximately 30 percent of the research personnel of Slovenia can be found in its industrial complexes. The annual number of graduating Ph.D.s, it is claimed, exceeds 1800. For undergraduate and graduate students, a special program of encouragement and support has been instituted, known as "young researchers."

Approximately 1 percent of the Gross National Product (of $ X) is directed into research and development. Forty percent of this goes into basic research, a lesser amount into applied research and 30 percent into education. This well-educated and research-oriented population should assure the social, economic,and cultural success of Slovenia, once her full independence is established.

The Slovene Ministry of Science and Technology consists of six divisions: R & D, Infrastructure, Informatics, International Cooperation, Standardization and Metrology, and Industrial Property Protection Office. The Slovenian Academy of Sciences and Arts is the country's oldest scientific institution, tracing its origin to the sixteenth century. It is divided into sections for the natural sciences, medical sciences, philosophy and social sciences, history and the study of social classes, and the arts. It is interesting to note that with Slovenia's declared independence one of the major areas of emphasis has been their concern for preservation of the environment. Such emphasis was not particularly evident under the communist Yugoslavian government.

The largest university in Slovenia is the University of Ljubljana. It consists of 24 Faculties (departments), with 790 full and associate professors, an additional faculty of 500, and more than 22,000 students. The University collaborates with a number of Slovene research institutes including the world-renowned Jozef Stefan Institute, the Boris Kidrič Institute, and Institutes for Geography, Mathematics, Physics, etc. Recently, a large Computer Center was established in Ljubljana, along with a new Center for Research and Development. In addition, the University has cooperative studies with more than 25 other universities worldwide. Its sister university, the University of Maribor, has three Faculties, approximately 225 faculty members and 11,000 students, and maintains an active program with industry in the Štajerska area of Slovenia.

The Research Institutes of Slovenia are numerous (some 36, most of which most treat basic or applied research). A few are primarily directed toward development. The institutes include those for Biology, Mathematics, Physics, Chemistry, Medicine, Electronics, Geology, Forestry, Metallurgy, Seismology, Railways, Turbines, Electrical Engineering, Metal Construction, Mining, Paper, Water Management, Urban Development, Textiles, Pedagogy, Economics and Marketing, Social Science, Administration, Brewery, and Law.

The Jožef Stefan Institute is an example of one of the larger Institutes. The Institute has a total staff of approximately 925 employees, of whom 560 are scientific staff, with 200 having doctorate degrees and 114 masters degrees. Approximately 70 scientists have permanent appointments in various departments at the University of Ljubljana. The staff publishes about 900 scientific papers each year.

Major equipment at the Institute includes: TRIGA research reactor (250 kW), Van de Graaff (2 MeV), low- and high-resolution mass spectrometers, nuclear pulse and double resonance magnetic spectrometers, electron microanalysis, instruments for thermal and X-ray analysis, DEC VAX 8650

System CONVEX 220-128E, protein sequencers, DNA synthesizer, and equipment for recombinant DNA techniques, to name only a few.

With its declaration of independence, Slovenia is embarking on a revitalized scientific, social, and economic program that is geared to both its immediate and its long-term needs in the European community. In general, Slovene scientists (as expressed in their recent meetings within the country and in the Ljubljana daily newspaper *Delo*) are encouraging their new political officials to put greater emphasis on education and research. During a recent visit, it was obvious that an immediate problem in formulating a stepped-up program has been determining what an adequate budget should be in view of Slovenia's withdrawal from Yugoslavia. The entire financial structure of the country, including its banks, is being reorganized. Its currency has been changed. Having visited Slovenia for almost 25 years and taught in her universities and institutes, it appears very probable that these industrious and well-educated people will be able to establish a very workable democracy.

Underwater Acoustics

Transmission Line Matrix Modeling: Novel Approaches to Analysis of Underwater Acoustics

by CDR Joseph McGowan, USNR, P.E., M.S.E., a visiting scientist/reserve officer to the Office of Naval Research European office, and a Field Officer with the Naval Reserve Technology Mobilization Management Team. He is a Ph.D. candidate at the University of Pennsylvania studying magnetic resonance.

KEYWORDS: submarine, sound, sonar, parallel processing, wave propagation

INTRODUCTION

Transmission line matrix modeling (TLM) is a method of numerical analysis arising from Huygen's principle that a wavefront consists of a number of secondary radiators producing spherical wavelets.[1] First introduced in 1971 by P.B. Johns and R.L. Buerle, it was used to investigate microwave scattering caused by a waveguide bifurcation.[2] Subsequent investigators pointed out its equivalent utility in diverse wave propagation problems, and TLM modeling has recently been applied to problems ranging from heat diffusion to acoustic propagation.[3] By providing a true computer simulation of wave propagation in the time domain, TLM differs significantly from the majority of commonly used numerical techniques, which yield harmonic solutions of Maxwell's equations in the space or spectral domain. Important advantages of TLM include

- relatively simple inclusion of complex boundary conditions and geometries,
- inherent suitability of the technique for parallel implementation,
- inherent unconditional stability, and
- ease of obtaining families of solutions to complicated problems without recalculation.

Application of TLM techniques is a subject of ongoing investigation at the University of East Anglia, Norwich, United Kingdom, where TLM modeling extends to acoustic propagation, stress

analysis, transducer design, chromatography, chemical reaction kinetics, and laser/surface interactions. Research into optimization of TLM algorithms is also being pursued, as well as incorporation of probabilistic techniques. This paper summarizes discussion during a recent visit with Dr. Donard de Cogan, Senior Lecturer in the School of Information Systems of the University of East Anglia, Norwich NR47TJ, United Kingdom (telephone 011-44-0603-56161). Dr. de Cogan collaborated with the late Peter Johns, original developer of TLM modeling. In addition, Mr. Peter Willison, a graduate student completing Ph.D. research, provided helpful discussions and examples of experimental results.

THEORETICAL BASIS OF TLM

The TLM model uses electrical networks to simulate the medium through which a wave travels. Thus, the propagation space is filled with a network of transmission lines, allowing delta function impulses to traverse the network. Analysis of the problem proceeds in discrete time steps, yielding results in terms of the input delta functions. Theoretically, the calculated response will contain information for all input frequencies, although in practice the frequency response information has an upper limit determined by the spacing of the transmission line network.

A TLM network in two dimensions is made up of a Cartesian mesh of open 2-wire transmission lines. Each junction between two transmission lines forms a node (Fig. 1), which becomes the theoretical site for all scattering. This being accepted, it is possible to evaluate the transmission line mesh (for the most part) with little or no knowledge of transmission lines![4] Consider the mesh diagrammed in Fig. 2, with a single incident impulse of 1 V approaching the central node from below. The energy is scattered isotropically in all four directions, resulting in a reflected impulse of −0.5 V and three transmitted impulses of +0.5 V.[1] The most general case of four impulses being transmitted to a node is obtained by superposition. Therefore, if at time $t = k\Delta t$, voltage impulses V_n^{imp} are incident on a node from transmission lines 1-4, then the total voltage reflected along line n at time $t + \Delta t$ is

$$V_n^{reflected}(t + \Delta t) = \frac{1}{2}\sum_{m=1}^{4} V_m^{impulse}(t) - V_n^{impulse}(t).$$

The matrix form of this equation is simply

$$\begin{bmatrix} V_1 \\ V_2 \\ V_3 \\ V_4 \end{bmatrix}_{t+\Delta t} = \frac{1}{2}\begin{bmatrix} -1 & 1 & 1 & 1 \\ 1 & -1 & 1 & 1 \\ 1 & 1 & -1 & 1 \\ 1 & 1 & 1 & -1 \end{bmatrix} \times \begin{bmatrix} V_1 \\ V_2 \\ V_3 \\ V_4 \end{bmatrix}_t$$

where the 4 × 4 scattering matrix is formed by evaluating the reflection and transmittance of each line emanating from the node. Keep in mind that this equation does not depend on the state of any other nodes in the mesh. Thus it can be solved independently and simultaneously with the analogous equations for all other nodes. Furthermore, the impulses obtained from the solution of this equation become the incident impulses on lines for the four adjacent nodes in the next time step. Therefore, if the impulse voltages are known at all points in the mesh at any time step, the corresponding voltages can be calculated for all future times. This is done by simply operating either of the two preceding equations on each node in the network and then communicating the results of the operation to the adjacent nodes.

This model can easily be extended to include various boundary conditions, recognizing that the differences between nodes are completely contained in the scattering matrix. The problem of modeling diverse boundary conditions reduces to an appropriate selection of matrix elements and a spatial arrangement of nodes.

VERSATILITY OF THE MODEL

A boundary within the TLM mesh can be simulated by inserting a lumped circuit load (resistive, reactive, or a combination) across the transmission line, which describes the physical nature of the boundary, according to

$$\rho = \frac{Z_0 - Z_1}{Z_0 + Z_1}$$

and

$$\tau = 1 - \rho.$$

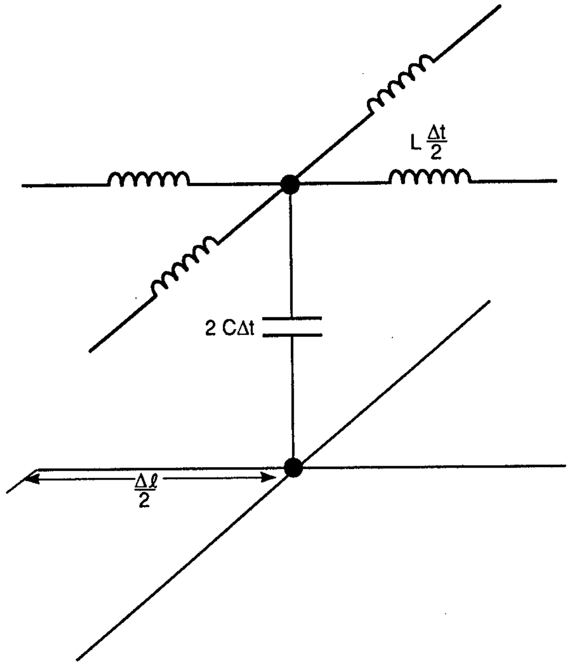

Fig. 1 — A single TLM node with connected transmission line components

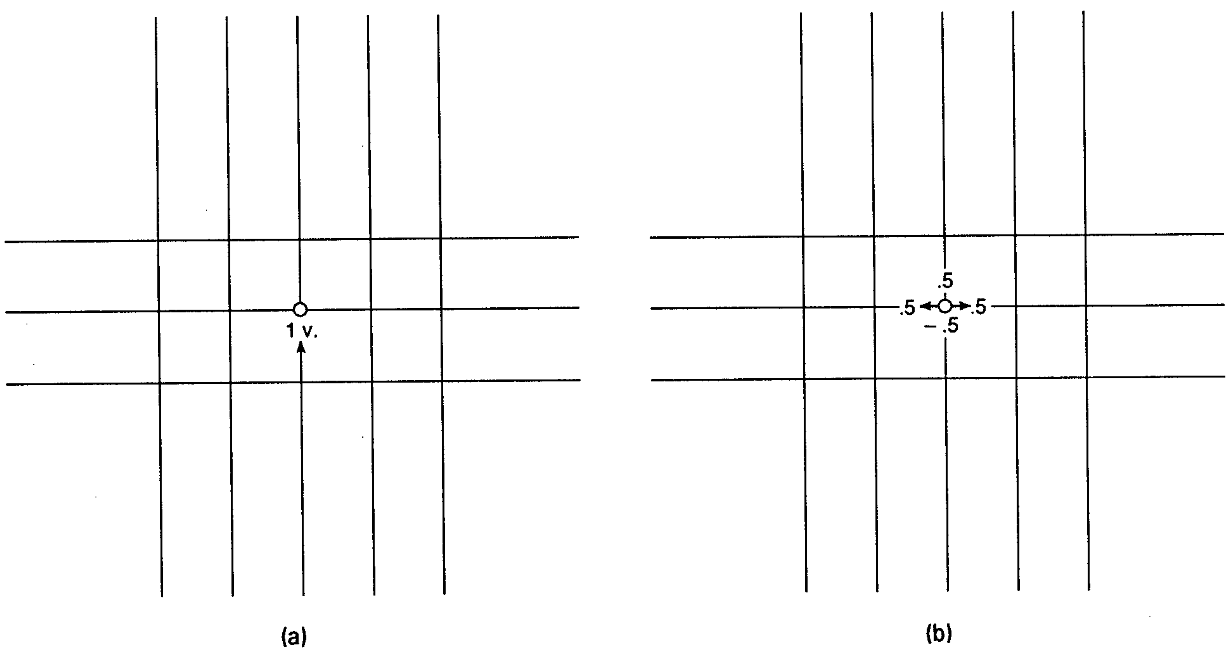

Fig. 2 — A 1-V impulse incident on a TLM node from below before (a) and after (b) scattering by the node

Here Z_0 is the characteristic impedance of the line, Z_1 is the boundary load impedance, and ρ and τ are the reflection and transmittance coefficients, respectively (analogous to probabilities of reflection and transmission). Load impedances are placed midway between nodes so that the pulse travel time between nodes will be the same as the time to reach a boundary load and return to the node.[5] An alternative representation uses reactive stub lines of length $\Delta 1/2$, where $\Delta 1$ is the length of a mesh transmission line and the stub is loaded with an appropriate characteristic impedance,[1] permittivity, or permeability.

Target boundaries (edge of mesh) can be modeled as rigid (infinite resistance) by terminating the mesh in open circuits or as "pressure release" by terminating the mesh in short circuits.[5] General boundaries, such as the end of the mesh that is not in contact with the source or target, can be modeled by coupling the mesh to the appropriate reactive load.

TLM can be applied to problems outside of electromagnetics by substituting appropriate variables for acoustic simulation:

Electrical	**Acoustic**
Voltage, V	Pressure, p
Current, I	Displacement, u
Capacitance, 2C	Compressibility, σ
Inductance, L	Density, ρ

The TLM approach is valid in up to three dimensions,[1] although acoustic applications to date have primarily been in one or two dimensions.

Finally, this discussion has centered on the shunt configuration of transmission lines, but the model can be extended to different electromagnetic applications by using a series layout; it can also be used to solve nonlinear lumped networks.[6,1]

ADVANTAGES OF THE TLM APPROACH

An important advantage of TLM modeling is the ability to simulate multiple complex boundary conditions within a single algorithm. Once the scattering matrix for a particular boundary has been determined, the same matrix is applied wherever that boundary appears along the mesh nodes. Additionally, once the composition of the mesh is determined, any desired input pulse can be applied at any point in the mesh without reprogramming.

If the input is selected to be a delta function, the output at any point will be an infinite series of discrete pulses of finite magnitude, representing the system response. Through Fourier analysis, the output corresponding to any other input can be obtained by convolving the input with the impulse response. This aspect of the TLM approach may represent substantial savings in computational overhead, since the responses to all frequencies for which the mesh is valid [empirically determined to be those frequencies for which $\Delta 1$ (the mesh spacing) is less than 0.1λ, where λ is the acoustic wavelength] are obtained by solving the mesh once.

As an example of computational efficiency, a comparison between a TLM approach and the method of moments is given in the user's manual for a three-dimensional solver that is commercially available (STRIPES, Version 1.3, Kimberley Communication Consultants, Nottingham, U.K.). This document states that, for solution of identical problems, the number of computational steps increases as the third power of the number of (cubic) nodes in the TLM method, as opposed to increasing as the fourth power in method of moments.

The inherent stability of the TLM technique is a significant advantage in situations where explicit finite-difference techniques are unstable due to constraints of mesh size or time step. In these situations the finite-difference model is required to be implicit and computational load is increased.

EXPERIMENTAL RESULTS AND WORK IN PROGRESS

Figures 3 and 4 show examples of simple wave propagation through a TLM mesh. These solutions are in agreement with analytical methods and demonstrate the validity of the TLM approach for modeling plane and curved wavefronts in two dimensions. A similar mesh was applied to the problem of a solid boundary (sea floor) and a reflective sea surface (Figs. 5 and 6).[7] These results demonstrate the potential for modeling more complex acoustic propagation problems.

The TLM approach is particularly well suited for implementation on parallel processing machines because of the inherently parallel nature of the

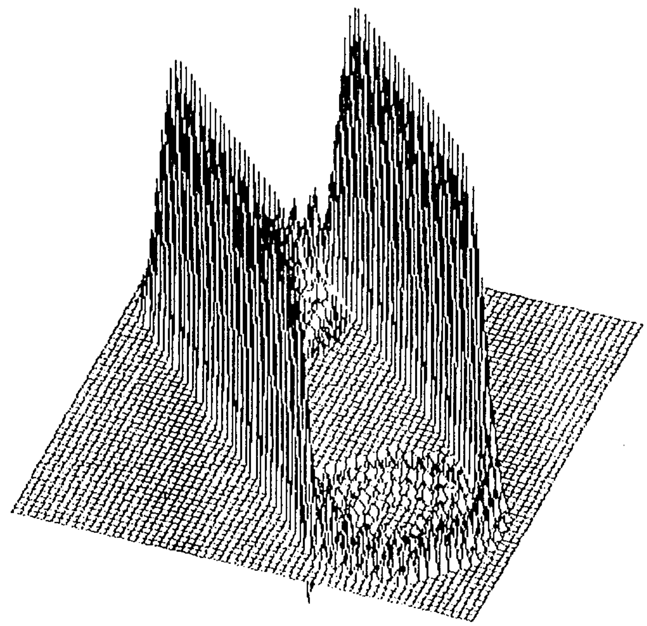

Fig. 3 — Results of a plane impulse centrally launched at 45-deg rotation from the axes in a two-dimensional TLM mesh. Note the "leakage" of energy at the edge of the wave. ©P.A. Willison, 1992, used by permission.

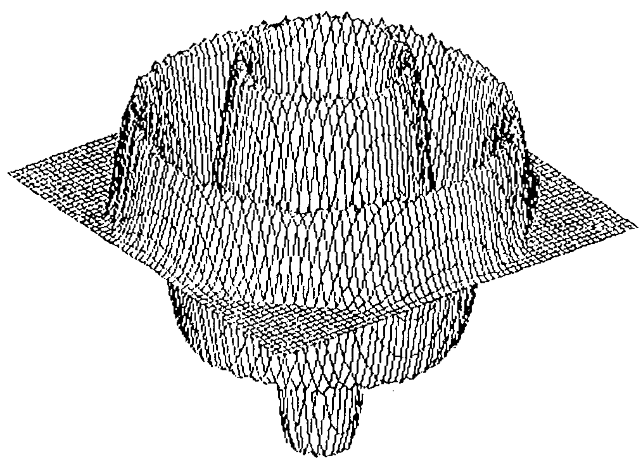

Fig. 4 — Results of a sinusoidal point source input to the central node of a two-dimensional TLM mesh. ©P.A. Willison, 1992, used by permission.

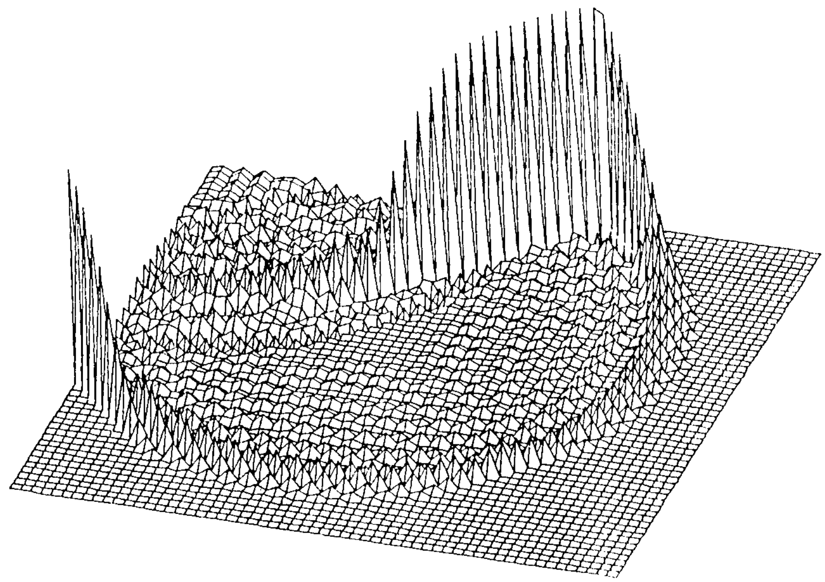

Fig. 5 — Results of a plane wave launched at a 45-deg angle into the center of a TLM mesh (along the line from top left to lower right) with a hard reflecting top boundary (model for hard ocean floor). ©P.A. Willison, 1992, used by permission.

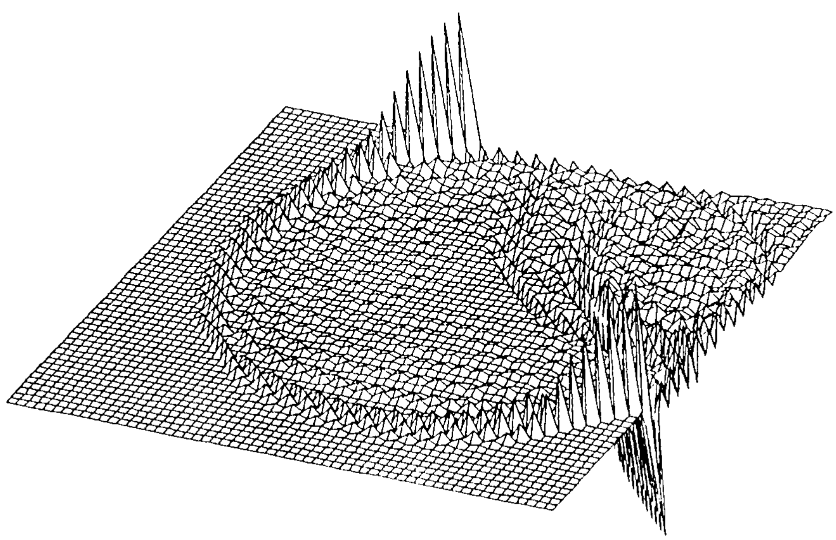

Fig. 6 — Results of a plane wave launched at a 45-deg angle into a TLM mesh (axis of launch is along the line from top right to lower left). A "pressure release" or sea-surface-type boundary appears on the right. Note the phase inversion in the reflected wave. ©P.A. Willison, 1992, used by permission.

calculations and the relative ease of coding these algorithms. The mesh can be divided geometrically between any number of processors so that each processor need calculate only the node voltages in the assigned subset mesh. Since the only communication required is between adjacent nodes, each processor is required to pass its outer node values to the neighbor processors only once per time step. Note that the TLM process is not iterative. Only one calculation is performed per time step, which is determined by the mesh spacing.

The algorithm was implemented on a 128 × 128 mesh by using (computer language) OCCAM 2 and a MEIKO (MEICO PLC, Bristol, U.K.) computing surface with eight T800 Transputers (INMOS PLC, Bristol, U.K.) each with 2 megabytes of local memory. Results indicated speed increases of 12 and 21 times over serial implementation on Sun-3 (Sun Microsystems, California, U.S.) machines with floating-point acceleration and 68881 co-processor, respectively. Additionally, the efficiency of the algorithm (defined as t_1/nt_n with t_1 the time to run on one processor, n the number of processors, and t_n the time to run on the parallel implementation) was near 90%, and essentially independent of the number of processors. This indicates that communication time is minimal, a requirement for efficient parallel processing.[8]

In treating more realistic situations, for example the sea surface boundary, one may invoke a natural probabilistic extension to this technique. The mesh boundary nodes at the sea surface are modeled with the addition of stubs that define sound speed at that point. The sound speed (and hence stub reactance) values are allowed to vary within certain bounds determined by (for example) sea state. Calculation of the mesh proceeds in time during the random variation, and parameters may be changed during the calculation. Again, the TLM method, which allows a single node to be manipulated independently, is inherently well suited for this approach. Work in this area is in progress at the University of East Anglia.

Further research is aimed at the development of a clearer understanding of errors inherent in TLM and the demonstration of analogues with other, particularly probabilistic, techniques. For the future, TLM will be applied in the study of power lasers, with the aim of developing a totally self-consistent coupled nonlinear model of field, thermal, and stress variables.

LIMITATIONS AND ERRORS

Peter Johns outlined three primary sources of error in TLM modeling of up to two dimensions:

- the impulse response must be truncated in time,
- the propagation velocity in the TLM mesh depends on the direction of propagation and on the frequency, and
- the spatial resolution is limited by the finite mesh size.

The resulting errors will be briefly discussed.

The truncation error results from the finite duration of the impulse response so that the Fourier transform of the response is not a line spectrum but rather a superposition of sin x/x functions that may interfere with each other. This phenomenon is well understood and can be mitigated by proper selection of node spacing and the time over which the algorithm is allowed to proceed.

The velocity error results from the fact that the propagation velocity is nonuniform and is maximized along the directions of the mesh coordinate system. If the wavelength in the network is large, it can be assumed that the fields propagate with the same velocity in all directions. Otherwise, the mesh spacing is again the controlling parameter. The velocity variation (dispersion) has been found to be comparable to similar errors introduced in the finite-difference algorithm.[9]

The coarseness error results when the size of the mesh is too large to model precise geometric features of the boundaries. The mesh spacing can be set in accordance with the smallest feature that needs to be modeled. Alternatively, a variable mesh spacing can be introduced, at the cost of increases in computational overhead and coding complexity.[10]

The limitations of mesh spacing can be addressed by hybrid models that use TLM analysis of source and target and conventional ray propagation

models to connect the source and target meshes. Such a model was proposed and investigated by E. A. Orme and collaborators, who incorporated two-dimensional Fourier analysis to detect and identify plane waves on the TLM mesh.[5] This may lead to a realistic way to model acoustic propagation problems that encompass target classification and localization.

SUMMARY AND CONCLUSIONS

This paper has described the basic formulation of the TLM technique and acoustics-related areas in which it has been applied, as well as ideas that have demonstrated promise for future application. As far as computational expenditure is concerned, the TLM method is reported to compare favorably with finite-element and finite-difference algorithms.[1] Its main advantage is the ease with which complex structures and boundary conditions can be incorporated into the model. There are no problems with stability, convergence, and spurious solutions. Another important advantage results from the fact that the impulse response generates, through the Fourier transform, the response to broadband, pulsed, and all other inputs. The method is limited by mesh size requirements that increase the computational load. However, these limitations can be overcome by the continual increase in computational capabilities or the combination of TLM techniques with complementary conventional (such as ray tracing) techniques. Continued development of TLM may lead to an enhanced ability to detect, localize, and identify underwater targets. The TLM method may find further usefulness in research involving solutions of wave, diffusion, or equations of similar form.

REFERENCES

1. W.J.R. Hoefer, "The Transmission-line Matrix Method–Theory and applications," *IEEE Transactions on Microwave Theory and Techniques* **MTT-33**(10), 882-893 (1986).

2. P.B. Johns and R.L. Buerle, "Numerical Solution of 2-Dimensional Scattering Problems Using a Transmission Line Matrix," *Proceedings of the IEE* **118**(9), 1203-1208 (1971)

3. R.F.W. Coates and D. de Cogan, "Transmission Line Matrix Modelling Applied to Problems in Underwater Acoustics," in Proceedings of Oceans '90, Washington, D.C., 1990. Available from IEEE, New York (publication CH2858-9/90/0000-0216)

4. D. de Cogan and P. Enders, "Microscopic Effects in TLM Heat Flow Modeling," Proceedings of IEE Tutorial Symposium on TLM, November 1991.

5. E.A. Orme, P.B. Johns, and J.M. Arnold, "A Hybrid Modelling Technique for Underwater Acoustic Scattering," *International Journal of Numerical Modelling* **1**, 189-206 (1988).

6. P.B. Johns and M. O'Brien, "Use of the Transmission-line Modelling (T.L.M.) Method to Solve Non-linear Lumped Networks," *Radio Electronic Engineering* **50**(1-2), 59-70 (1980).

7. P.A. Willison, unpublished data, 1992.

8. R.F.W. Coates and P.A. Willison, "A Transputer Implementation of the Transmission-Line Matrix Model as Applied to Underwater Acoustic Propagation," SERC/DTI Transputer initiative mailshot, 42-48, August 1990.

9. D.H. Choi, "A Comparison of the Dispersion Characteristics Associated with the TLM and FD-TD Methods," *International Journal of Numerical Modelling: Electronic Networks, Devices, and Fields*, **2**, 203-214 (1989).

10. P.B. Johns, "Application of the TLM Method to Homogenous Waveguides of Arbitrary Cross Section," *IEE Proceedings* **119**, 1086-1091 (1972).

THE EMBASSIES: TECHNOLOGY ROUNDUP

For further information on EC items, contact Mr. Anthony F. Rock, Science Counselor, U.S. Mission to the European Communities, American Embassy, Brussels, APO AE 09724-1030. Information on referenced programs is available in published European Community documentation.

KEYWORDS: Framework Programs; design and manufacturing; advanced materials; ESPRIT Program; RACE Program

INTRODUCTION

This article describes the principal European Community (EC) research and development (R&D) programs. EC R&D is organized in the form of 5-year "Framework Programs" of high-priority activities. These framework programs overlap to permit "rolling program planning." For this reason, some projects are still active under the second Framework Program (1987-1991); others have been defined and are commencing under the third Framework Program (1990-1994); and plans are under way for the fourth Framework Program (1993-1997).

INDUSTRIAL AND MATERIALS TECHNOLOGIES

The principal objectives of this initiative, with a 1990-1994 budget of 748 million ECU [as of 4 Sept. 1992, the European Currency Unit (ECU) was trading at U.S. $1.42 to 1 ECU], are to rejuvenate European manufacturing industry by reinforcing its R&D base, stimulating the integration of new technologies, and establishing standards and codes of good practice for technology transfer. A special effort will be made to help small and medium-sized enterprises become more involved in transnational research and better manage their technical resources. The environmental aspects of products and processes and the working environment are included as strategic elements in all parts of the program.

Principal Areas of Research

The aim is to improve the performance of materials at a cost that permits industrial competitiveness over a broad range of applications rather than over only a few high-performance items. Innovative use of industrial minerals, natural stone, metals, and industrial materials, is emphasized, including

- Raw materials: improving existing processes and mastering new and competitive technologies;
- Recycling: reinforcing the scope and effectiveness of recycling technologies; and
- Developing new and improved materials and their processing, including conventional mass commodity materials with enhanced properties and performance at a reasonable cost; advanced structural materials for high-performance systems (i.e., metals, ceramics, polymers, and their associated composites); advanced functional materials (such as conducting polymers, high-performance magnets, and novel electronic materials); surface engineering; and joining technology.

Design and Manufacturing

The aim is to improve the capability of industry products that are, at the same time, of high quality, easy to maintain, highly competitive, and environmentally and socially acceptable. Research will be directed to applications in current disciplines (such as physics, chemistry, mechanics, optics, acoustics, fluid dynamics, mathematical modelling, and process engineering) and their integration into new technological developments such as optomatronics (optics, materials, and electronics), mechatronics (mechanical engineering, computing, and electronics), microtechnology and micro- and nanostructural engineering, including molecular engineering:

- Design: impact on product performance, reduction of design time, manufacturing, and life cycle costs; and

- Manufacturing: efficient and cost-effective manufacturing processes, new tools and techniques, integration of chemical and process engineering, and integrating other aspects including the design interface, quality control, maintenance of facilities, and the working environment.

Aeronautics Research

The aim is to reinforce the technology base of the European aeronautics industry, minimize the impact on the environment, enhance the safety and efficiency of aircraft operations, and promote further cooperation between large high-technology companies and smaller companies, small and medium-sized enterprises, and research institutions and universities throughout the community:

- Environment and related technologies: reducing exterior and interior noise and exhaust emissions from aircraft

- Technologies of aircraft operation: maintenance technologies, health and usage monitoring, crashworthiness, fire risk control, and cockpit interfaces to the air traffic control system

- Aerodynamics and aerothermodynamics: computational fluid dynamics (CFD), techniques of drag reduction by laminar flow for subsonic and supersonic transport, propulsion integration, and the internal aerothermodynamics of turbo-machinery

- Aeronautical structures and manufacturing technologies: structural and materials application techniques relevant to primary aircraft structures and highly loaded high-temperature components and manufacturing processes particular to aeronautical applications

- Avionics systems technologies: design, integration, and evaluation of high-integrity avionics systems; particular techniques for sensing, monitoring, and controlling air vehicle systems; problems of man-machine interaction and flight-deck performance optimization

- Mechanical, utility, and actuation technologies: particular techniques for optimizing and exploiting new technology in aircraft mechanical systems, aircraft utility systems, and aircraft actuation subsystems.

Advanced Materials and Industrial Processes

The largest initiative of the second Framework Program in the industrial technologies is the BRITE/EURAM (Basic Research on Industrial Technologies for Europe/European Research on Advanced Materials) Program (1989-1992) with a budget of about 620 million ECU. An earlier BRITE Program (1985-1988) also addressed pre-competitive research and the application of new technologies. The EURAM Program concerns studies of advanced material technologies and their application.

The BRITE/EURAM Program extended beyond the earlier initiatives to include the application of manufacturing technologies, manufacturing processes, and aeronautics. The Aeronautics Program deals specifically with activities relating to aerodynamics, acoustics, airborne systems and equipment, and propulsion systems.

Raw Materials and Recycling

The Raw Materials and Recycling Program (1990-1992) deals with the supply and processing of primary raw materials such as minerals, recycling of waste and nonferrous metals, wool as a renewable raw material, and advanced materials.

JRC Activities in Advanced Materials and Structural Reliability

The Joint Research Center (JRC) also concluded an advanced materials program (1988-1991). Work started in 1984 on high-temperature materials such as steels, alloys, and ceramics. The program investigated the behavior of structural and functional materials, the properties of material

surfaces and coatings, and the improvement of existing materials or innovation of new ones.

The JRC was also responsible for a program on the reliability of structures (1988-1991). This covered studies of the components and materials used for construction work or in mechanical systems, with particular emphasis on component life and behavior under severe loading.

Iron and Steel

The European Coal and Steel Community (ECSC) is responsible for two programs in the industrial technologies area: a program concerning research (1986-1990) into steel production, processing, and consumption; and a program of pilot and demonstration projects in the iron and steel industry (1988-1992). Under the Cost Program, a materials program has been set up to support the European power engineering industry through work on high-temperature materials, on both concrete construction elements, on powder metallurgy, and on light alloys.

Transport

In the field of transport, 16 projects have been launched under the Cost Program. These mainly concern the application of new technologies, particularly in informatics and telecommunications, to traffic management, road safety, and marine navigation systems. The recent (1990-1993) Recherche dans le Transport en Europe (EURET) Program addresses the issue of economic efficiency, safety, and environmental acceptability of transport, particularly in the areas of track-guided transport, and road, sea, and air traffic.

INFORMATION AND COMMUNICATIONS TECHNOLOGIES

Introduction

This component of the European Community Third Research and Development Framework Program (1990-1994) is clearly the largest, with a total budget of 2.846 billion ECU. Activities in information technologies are dominated by the European Strategic Program for Research and Development in Information Technologies (ESPRIT) with its 1990-1994 budget of 1.78 billion ECU. The technological areas supported in ESPRIT are those considered to have long-term strategic impact:

- Microelectronics and peripherals technologies
- Information processing systems
- Office and business systems, and
- Computer-integrated manufacturing, together with the establishment of a basic information exchange system.

The principal telecommunications initiative is the Research and Development in Advanced Communications Technologies in Europe (RACE) Program, which is concerned with all aspects of integrated broadband communications (IBC). The RACE Program has a 1990-1994 budget of 566 million ECU.

The third EC R&D Framework Program also includes a comprehensive initiative on the development of Telematic systems throughout Europe, a program with a budget of 495 million ECU.

Information Technologies — The ESPRIT Program

The principal objectives of the ESPRIT program are to strengthen the technological base of the EC in the field of information technologies while accelerating the integration of these technologies in the business world, in manufacturing, and in private life. These activities are complimentary to other existing programs at the EC, national, and international levels.
The ESPRIT program addresses five principal areas:

1. Micro-electronics:

   - to strengthen the European technology base in integrated circuitry in support of future manufacturing capability [strategic work on very advanced submicron CMOS [complementary (symmetry) metal oxide semiconductor] technologies will be carried out in

conjunction with the European Research Coordination Agency's (EUREKA) Joint European Submicron Silicon Project (JESSI)]

- to strengthen the capability in the EC with respect to the chain of designing, manufacturing, testing, and applying advanced and reliable integrated circuits, and

- to ensure wide participation of the largest number of potential actors (large and small industries, both producers and users, universities and research centers) in the community [Note: particular emphasis will be placed on application-specific integrated circuits (ASICS)].

2. Information processing systems and software:

   - to exploit potential technological breakthroughs in concurrent architecture

   - to provide better interfaces to satisfy the needs of end-users, and

   - to promote the take up of new software production technologies.

3. Advanced business and home systems — peripherals:

   - to establish functional integration in the business environment as well as in (and with) the home environment, easing the use of systems (an especially high priority will be given to pre-normative work)

   - distributed computing, including database management; microprocessor systems and technologies will be of major concern throughout the activities. Two complementary areas have been identified: (1) R&D activities concerning intelligent homes and intelligent buildings, and (2) R&D work on integrated business systems.

4. Computer-integrated manufacturing and engineering:

   - to provide the technology base for open systems, multivendor systems, and distributed operations in engineering and manufacturing environments, as well as

   - to contribute to better integration of advanced information technology (IT) systems components in engineering industries (the work will focus on new generations of basic computer-integrated manufacturing (CIM) technologies and on demonstrating their applicability in selected manufacturing and other engineering domains).

5. Basic research:

   - to maintain and to expand the scientific knowledge and expertise of the European IT community, with projects in this area based on:

   - their potential to produce future breakthroughs or important advances, even if they have no immediately visible application

   - their ability to benefit from the added value that cooperation on a European scale provides

   - their positioning clearly upstream of R&D efforts while contributing to the overall aims of the program.

Communications Technologies — The RACE Program

The principal objectives of the RACE program are to contribute to the introduction of integrated broadband communications (IBC) with the development of the Integrated Services Digital Network (ISDN), including the introduction of national IBC services by 1995; and to enable the Integrated Broadband Network to take on emerging new services, based on "open" standards and cost-effectiveness.

The new RACE activities are specifically directed toward developing intelligent, reliable and secure networks, and new value-added services that

are both profitable and adapted to the developing needs of users. These actions include a community R&D pre-normative to guarantee the interoperability of systems based on common standards and protocols. Particular attention will be given to the growing demand for mobile telephone services and the integration of these services into networks.

The RACE initiative includes eight priority areas:

1. Integrated broadband communications (IBC) research and development: systems approach to key technologies, systems, services, and applications, with emphasis on

   - IBC systems design, architecture, and operation
   - IBC transition strategies
   - common operational environment
   - techniques for basic IBC system functions
   - integration of IBC demonstrators, and
   - verification tools.

2. Intelligence in networks and flexible communications resource management: related to the use of new techniques of

   - information transfer
   - optical communications, and
   - possibly artificial intelligence for enhancing flexibility, both in the provision of new network services and network management.

3. Mobile and personal communications: contributing to the development of third-generation integrated mobile communication systems; the aim will be to provide universal personal communications using audio, data, and image (for cost-efficient implementation, third-generation systems will require a common radio interface).

4. Image and data communication: involving the development of the technologies needed for the introduction and exploitation of advanced, low-cost, and flexible image and data communication services for both business and domestic needs.

5. Integrated services technologies: to contribute to the definition of common functional specifications for new communication services and multimedia systems:

   - IBC/modular standardization: harmonization of architecture and specifications for the flexible integration of telematic services under user control
   - integrated service technologies: techniques for architecture realization, user components technologies, metaphors and user interface technologies, and service management systems
   - service technology verification: development of prototype facilities for flexible integration of services responding to the requirements of operators, service providers, and users.

6. Information security technologies: to ensure that considerations of quality, security, and reliability of service are included in development and implementation strategies for advanced communications. Work in this area will provide validated specifications, guidelines, and technology for practical and effective information security at a Pan-European level consistent with actions carried out in other community programs. Subjects include:

   - service quality, security, and reliability
   - information security technologies
   - information security verification.

7. Advanced communication experiments: designed to prepare the ground for and minimize the risks of investments in advanced communi-

cations. Work in this area will identify generic service functions that are reusable and will permit the matching of different user needs while maintaining universal access and interoperability. Subjects include:

- study of generic functions
- technology and techniques for advanced communications experiments
- application experiments.

8. Test infrastructure and interworking: test infrastructure is needed to validate standards and functional specification. Under conditions to be agreed on by the partners, the provision and operation of the test infrastructure is expected to be ensured by the operators and national testbeds, in collaboration with and cooperation between them when necessary for interconnection and interworking.

Telematic Systems

The principal objectives of this program are to ensure the interoperability of systems, peripherals, and telematic networks at Trans-European level, giving special attention to quality, reliability, security, and ease of use of services, and to economies of scale and the abolition of barriers to information exchange. The program is based on the experience and results obtained from exploratory activities (AIM, DELTA, DRIVE, INSIS, CADDIA, and TEDIS) briefly described later in this report.

Special account is being taken of the needs for management and transmission of electronic information as a consequence of completion of the single European market. Therefore, the program involves information and communications industries, telecommunications operators, providers of telecommunications services, and users of advanced communications.

The activities are precompetitive and pre-normative and focus initially on interoperability between national systems. This includes defining standards, architecture, and functional specifications. Key activities in the telematics program include:

- supporting the establishment of Trans-European networks between administrations;
- defining common requirements for electronic information exchange and examining the need for interoperability between electronic information networks within member states;
- carrying out studies and pre-normative research for the definition and subsequent establishment of the Trans-European telematic services networks. These are essential to national administrations for completing the single market and for providing the services necessary for the free movement of person, goods, services, and capital; and
- increasing economic and social cohesion in the community.

In the first instance, work may concern such areas as customs, social services, emergency services, and statistics. Subareas include:

- identifying needs and implementation strategies,
- developing technologies relating to telematic services, and
- validating common functional specifications.

Transport Services

To contribute to the development, in the field of transport, of integrated Trans-European services by using advanced IT and communications to improve the performance (safety and efficiency) of passenger and goods transport services, and at the same time reduce the impact of transport on the environment.

A subarea of this comes under the road transport program DRIVE (dedicated road infrastructure for vehicle safety in Europe). This builds on the exploratory research in DRIVE (1988-1991) under the second Framework Program and in close

liaison with relevant EUREKA projects. Work in this area will cover the interface between road and rail transport as well as that between road and sea transport. The activities will be divided into three interactive parts:

- defining functional specifications in the context of a strategy for the use of technology and telematic systems for communication and traffic control,
- developing new technologies and experimental systems, and
- validation work.

Health Care (AIM)

To stimulate the development of harmonized applications of information and communication technologies in health care and the development of a European health-care information infrastructure, taking into account the needs of users and technological opportunities. Three main lines are using the exploratory work of the 1988-1989 AIM (advanced informatics in medicine) Program in close cooperation with other community programs:

- strategies for the use of technologies, telematic systems, and services and contribution to the definition of common functional specifications
- development of telematic technology applied to medicine
- validation and integration of systems.

Flexible and Distance Learning (DELTA)

Based on the exploratory work of the 1988-1990 DELTA (Development of European Learning Through Technological Advance) Program. The work in this area will be carried out in three interdependent parts:

- strategies for the use of technologies, telematic systems and services, and contribution to the definition of common functional specifications
- development of systems and technologies
- experiments on the validation and integration of services.

Libraries

To facilitate user access, by optimum use and development of equipment and telematic systems, to the wealth of knowledge held in libraries.

Linguistic Research and Engineering

To develop a basic linguistic technology that can be incorporated into a large number of computer applications where natural language is an essential ingredient. This requires the creation of linguistic resources (grammars, dictionaries, terminology collections, and basic texts) for the nine official community languages, and the definition of standards for these data. The area is divided into three parts:

- research,
- development of resources, and
- pilot applications.

It is based on the results and experience drawn from the European Translation Program (EUROTRA) and certain specific projects conducted under ESPRIT and national research programs.

Telematics Systems for Rural Areas (ORA)

- to develop a better understanding of the common needs and opportunities for telematic services and of the impacts of such services on rural life,
- to establish a common understanding of network configuration requirements and options, and a common understanding of service requirements for telematic services, and
- to prepare the way for the harmonized planning and introduction of telematic services infrastructures in rural areas.

Information and Communications Technologies — EC Programs to Date

The ESPRIT Program (1987-1992) has a budget of 1,600 million ECU. The projects of the earlier microelectronics program (1982-1985), particularly in the areas of CAD and VLSI, provided important input to the ESPRIT program. In addition, there are currently several smaller programs within the information technologies area concerning the application of telecommunications of informatics to specific sectors. These are

- Advanced Informatics in Medicine [AIM (1988-1989)]
- Cooperation in Automation of Data and Documentation for Imports/Exports and the Management of Financial Control of the Agricultural Market [CADDIA (1985-1992)]
- Dedicated Road Infrastructure for Vehicle Safety in Europe [DRIVE (1988-1991)]
- Inter-institutional Integrated Services Information System [INSIS (1982-1992)]
- Development of European Learning Through Technological Advance [DELTA (1988-1990)], and
- Trade Electronic Data Interchange System [TEDIS (1988-1989)].

These programs relate to medicine, import/exports and the agriculture market, road systems, community institutions, education, and commerce respectively. The EUROTRA Program (1971-1990) aims to develop a machine translation system for community languages. It is therefore concerned with both linguistic research and the creation of an operational prototype software system. In the third Framework Program, many of these programs have been incorporated under the telematics initiative. The RACE Program (1987-1992) preceded the current program to advance IBC (integrated broadband communications).

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